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(58) Field of Search by ISA
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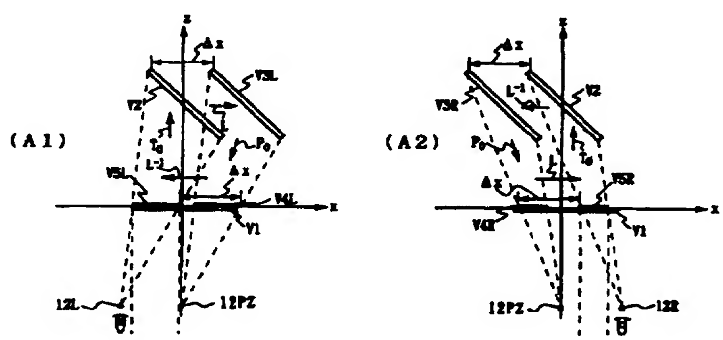
(54) Method and device for forming three-dimensional image

(57) Source image signals are converted into video signals for the left and right eyes by use of a spacial image transformation matrix and a perspective transformation matrix for perspective transformation onto a sreen. Thus, the three-dimensional image forming device can easily set the parallax between the left and right eyes.



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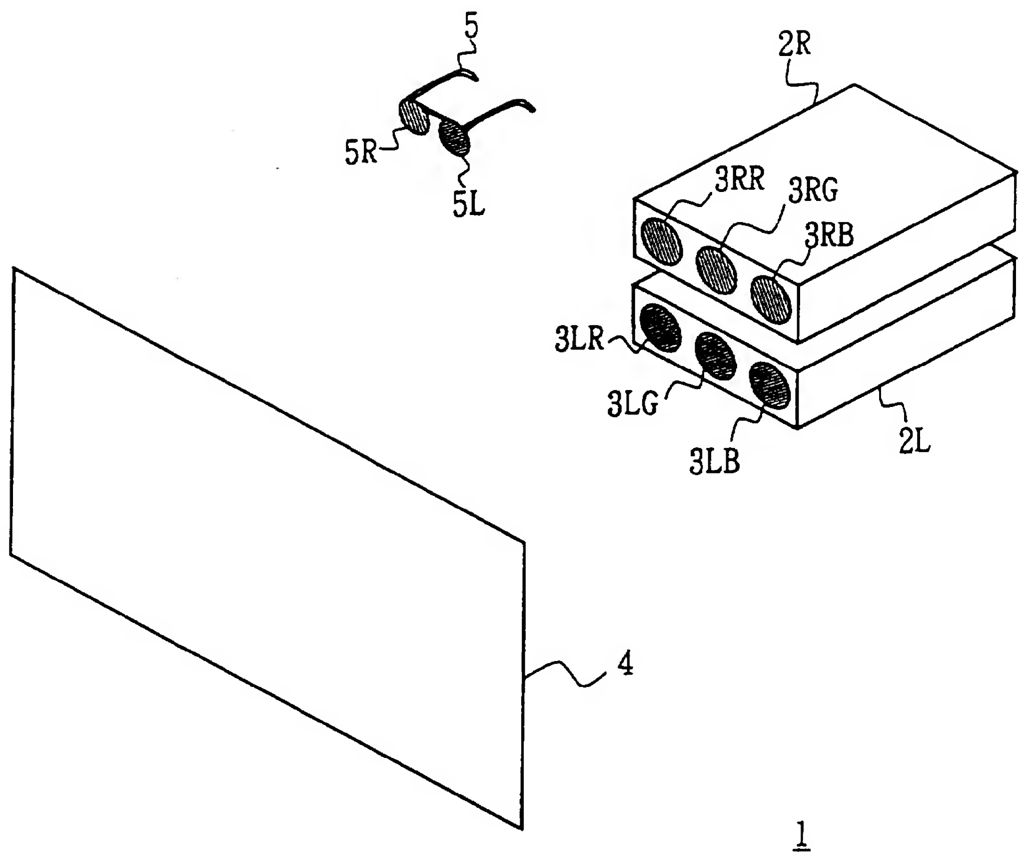


FIG. 1

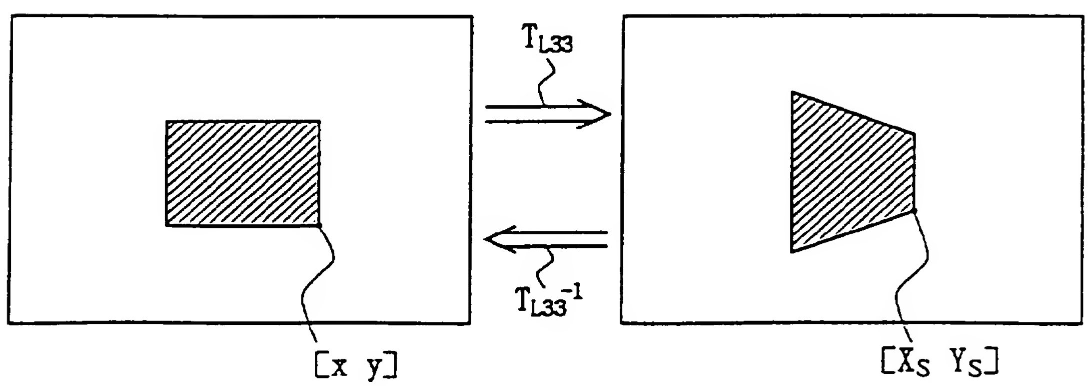


FIG. 5

FIG. 2 (A)

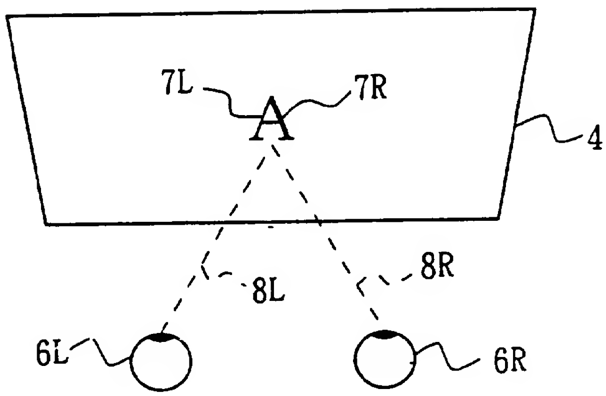


FIG. 2 (B)

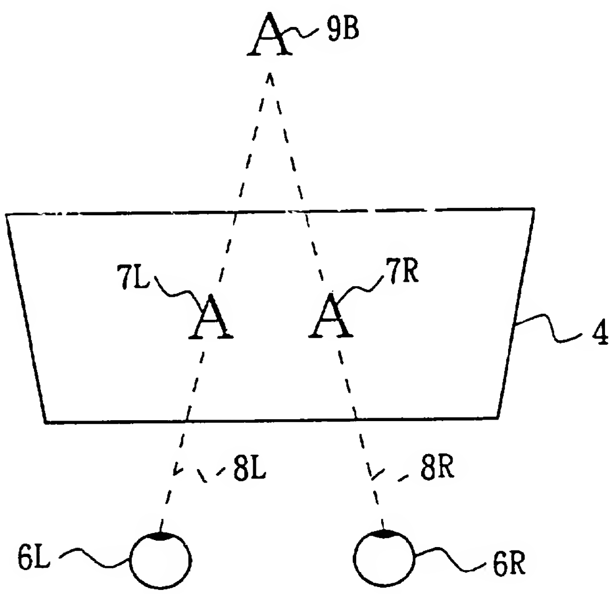
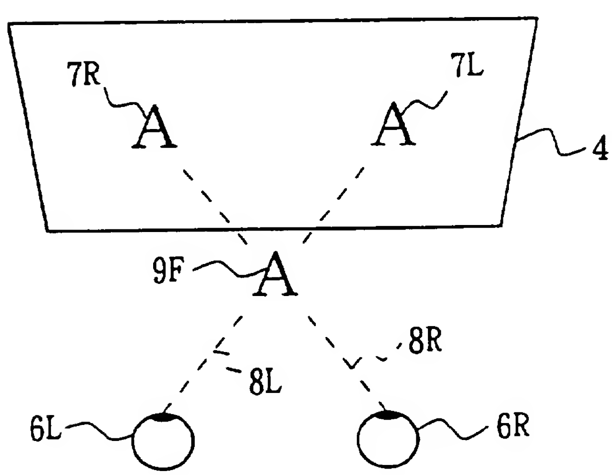


FIG. 2 (C)



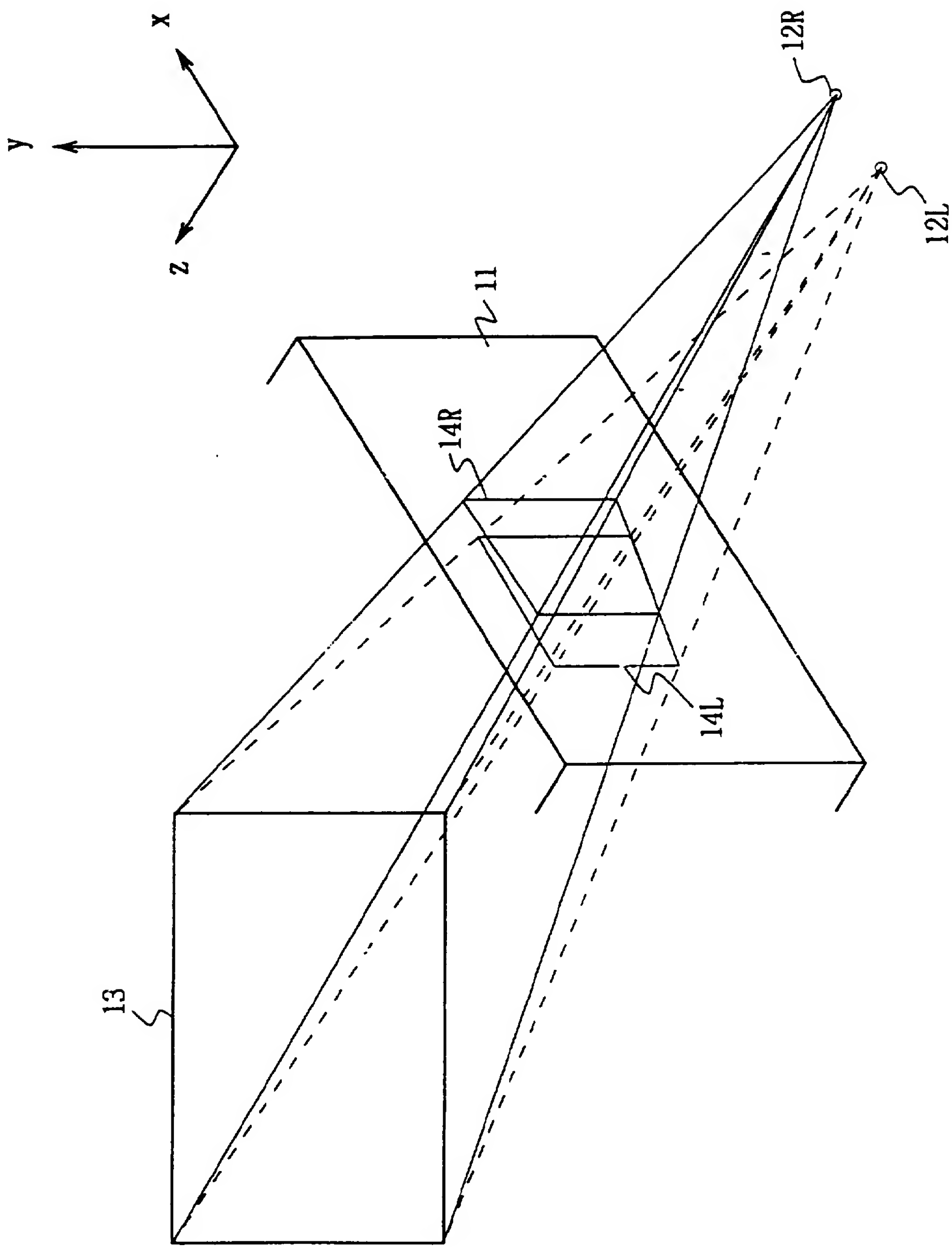


FIG. 3

FIG. 4 (A1)

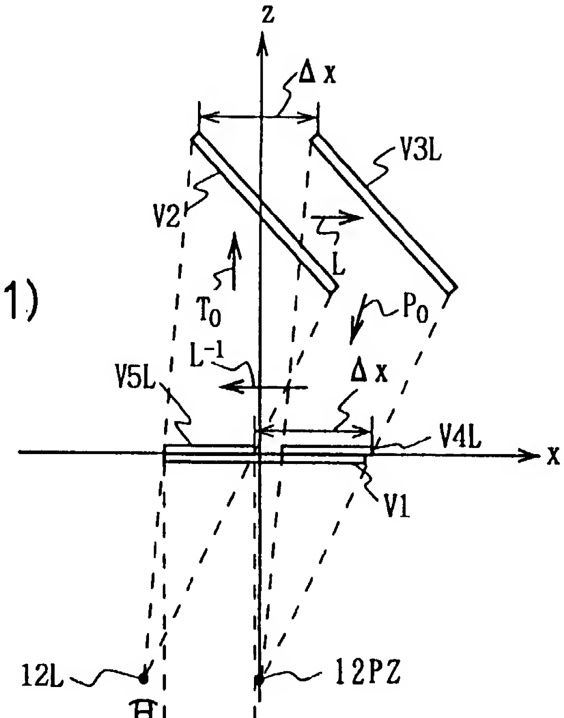


FIG. 4 (B1)

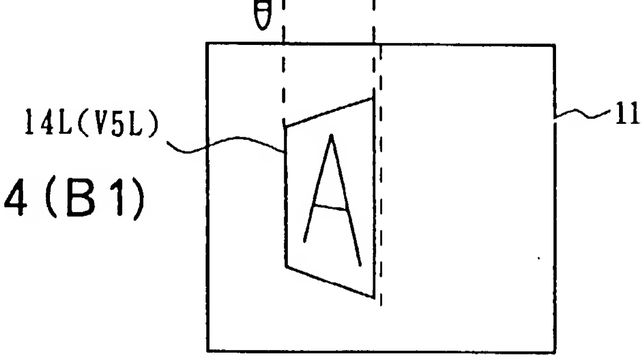


FIG. 4 (A2)

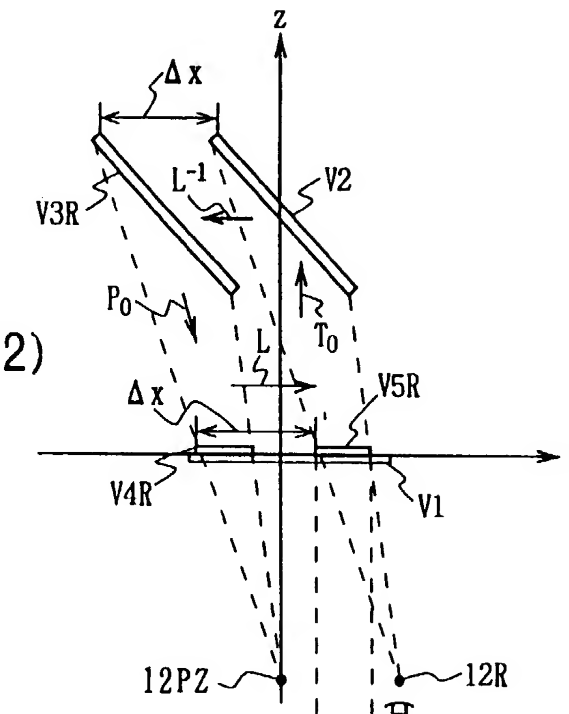
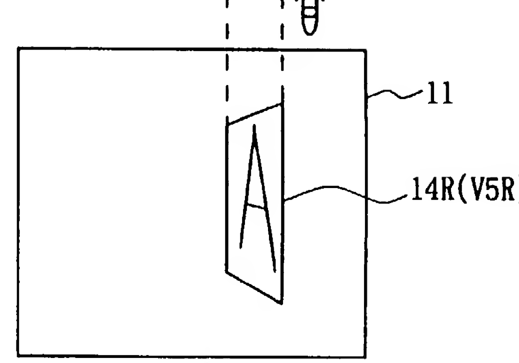
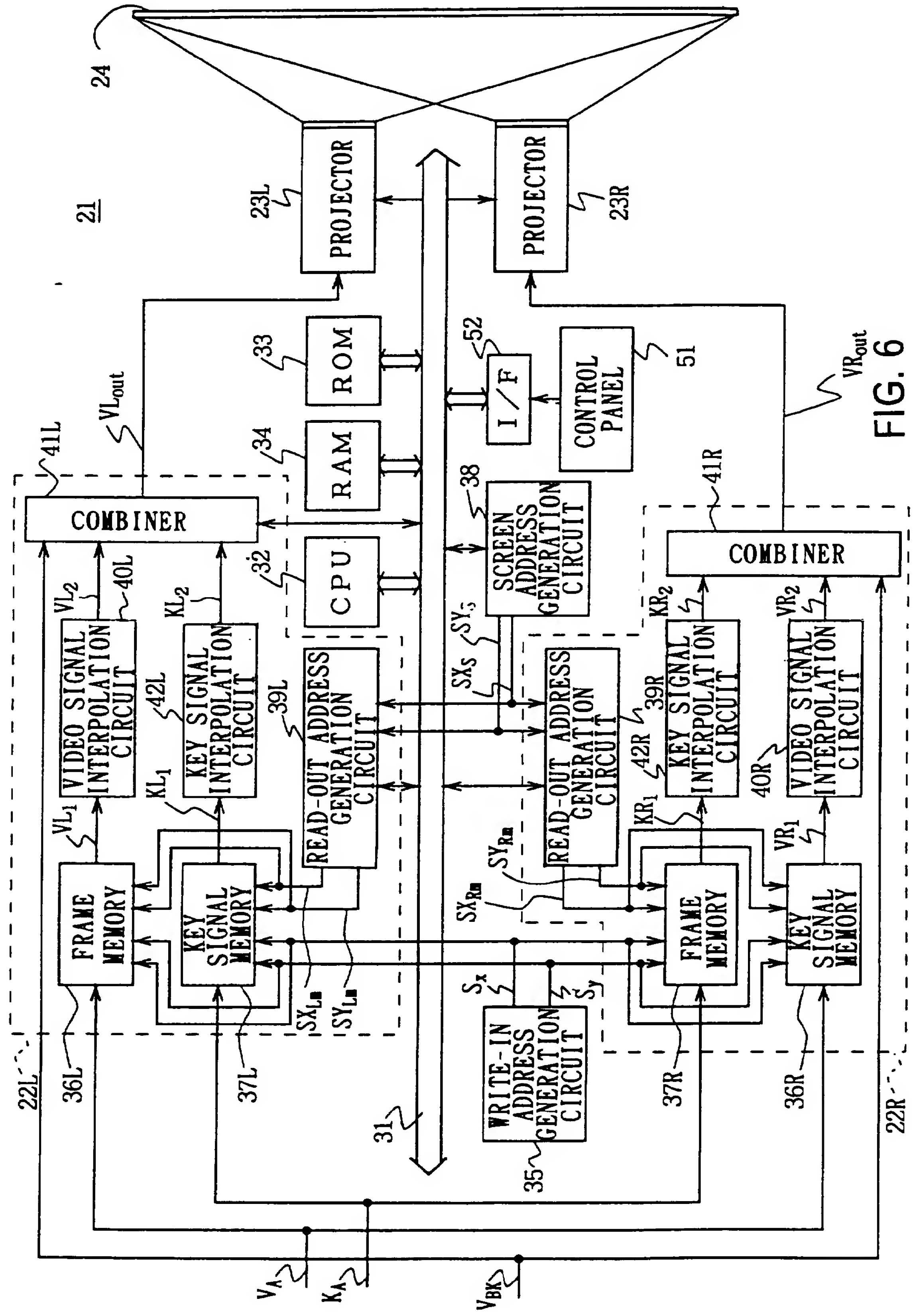
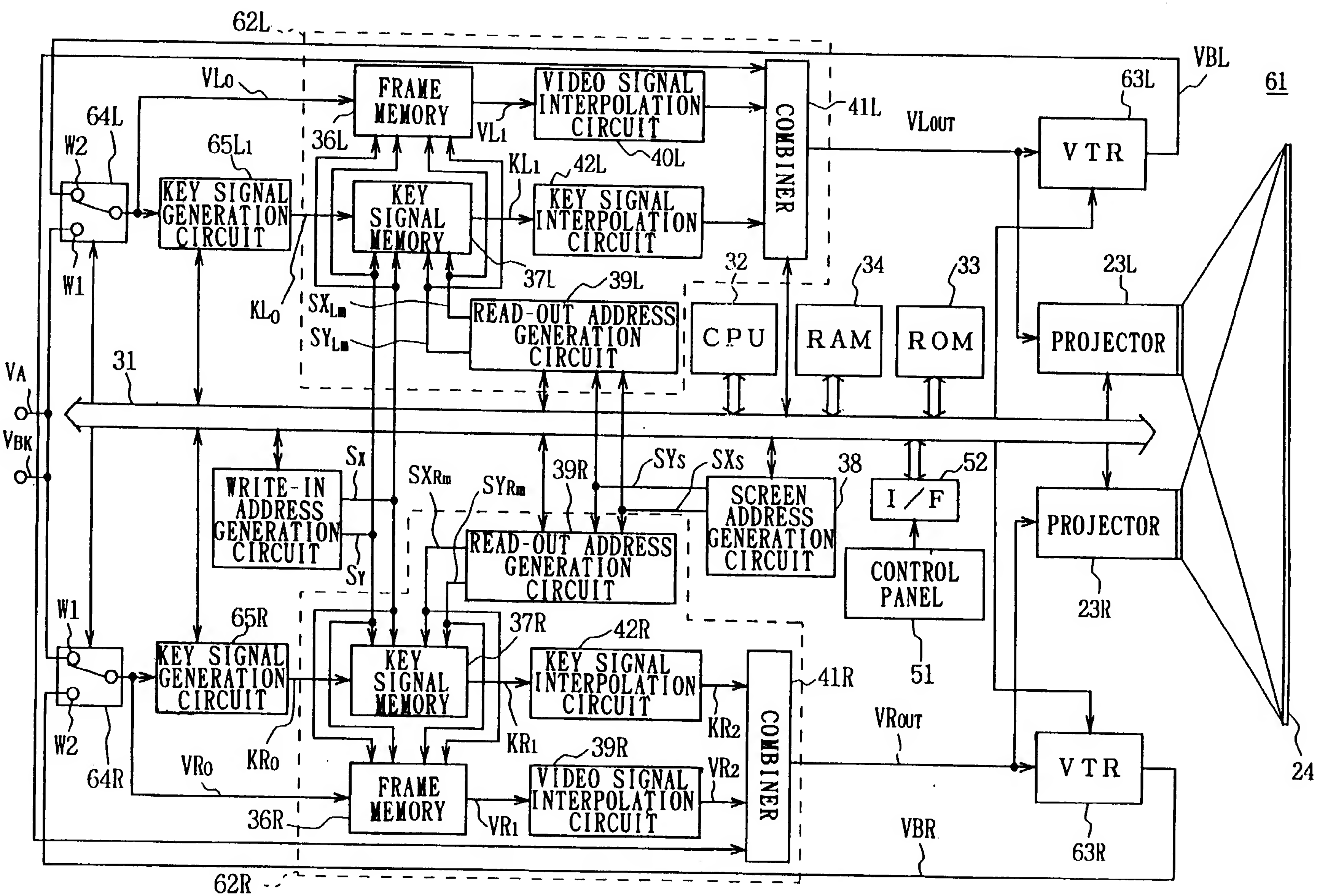


FIG. 4 (B2)




21
24
PROJECTOR
23L
PROJECTOR
23R
ROM
33
RAM
34
CPU
32
I/F
52
CONTROL PANEL
51
SCREEN ADDRESS GENERATION CIRCUIT
38
SX_S
SY_S
COMBINER
41L
VL_{out}
COMBINER
41R
VR_{out}
VIDEO SIGNAL INTERPOLATION CIRCUIT
40L
VL_1
VL_2
KEY SIGNAL INTERPOLATION CIRCUIT
42L
KL_1
KL_2
READ-OUT ADDRESS GENERATION CIRCUIT
39L
READ-OUT ADDRESS GENERATION CIRCUIT
39R
KEY SIGNAL INTERPOLATION CIRCUIT
42R
KR_1
KR_2
VIDEO SIGNAL INTERPOLATION CIRCUIT
40R
VR_1
VR_2
FRAME MEMORY
36L
KEY SIGNAL MEMORY
37L
SX_{Lm}
SY_{Lm}
FRAME MEMORY
37R
KEY SIGNAL MEMORY
36R
SX_{Rm}
SY_{Rm}
S_x
S_y
WRITE-IN ADDRESS GENERATION CIRCUIT
35
31
22L
22R
V_A
K_A
V_{BK}
FIG. 6



61
VBL
63L
VTR
23L
PROJECTOR
PROJECTOR
23R
VTR
63R
24
VBR
VLOUT
VROUT
62L
62R
41L
COMBINER
41R
COMBINER
FRAME MEMORY
36L
VIDEO SIGNAL INTERPOLATION CIRCUIT
40L
KEY SIGNAL INTERPOLATION CIRCUIT
42L
KEY SIGNAL MEMORY
37L
READ-OUT ADDRESS GENERATION CIRCUIT
39L
VL0
VL1
KL0
KL1
SXLm
SYLm
64L
W1
W2
65L1
KEY SIGNAL GENERATION CIRCUIT
VA
VBK
31
32
CPU
34
RAM
33
ROM
52
I / F
CONTROL PANEL
51
38
SCREEN ADDRESS GENERATION CIRCUIT
SXS
SYS
WRITE-IN ADDRESS GENERATION CIRCUIT
SX
SY
SXRm
SYRm
39R
READ-OUT ADDRESS GENERATION CIRCUIT
37R
KEY SIGNAL MEMORY
42R
KEY SIGNAL INTERPOLATION CIRCUIT
39R
VIDEO SIGNAL INTERPOLATION CIRCUIT
FRAME MEMORY
36R
65R
KEY SIGNAL GENERATION CIRCUIT
64R
W1
W2
VR0
VR1
VR2
KR0
KR1
KR2

FIG. 7

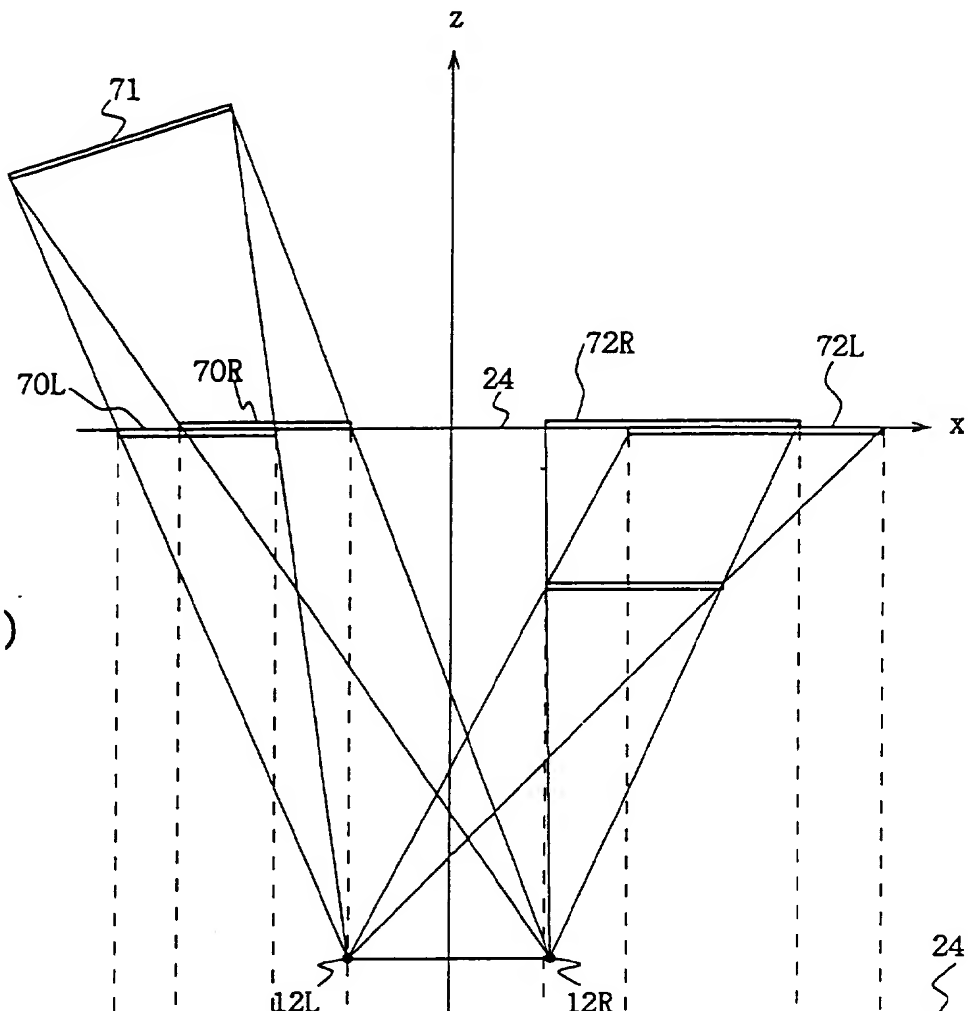


FIG. 8 (A)

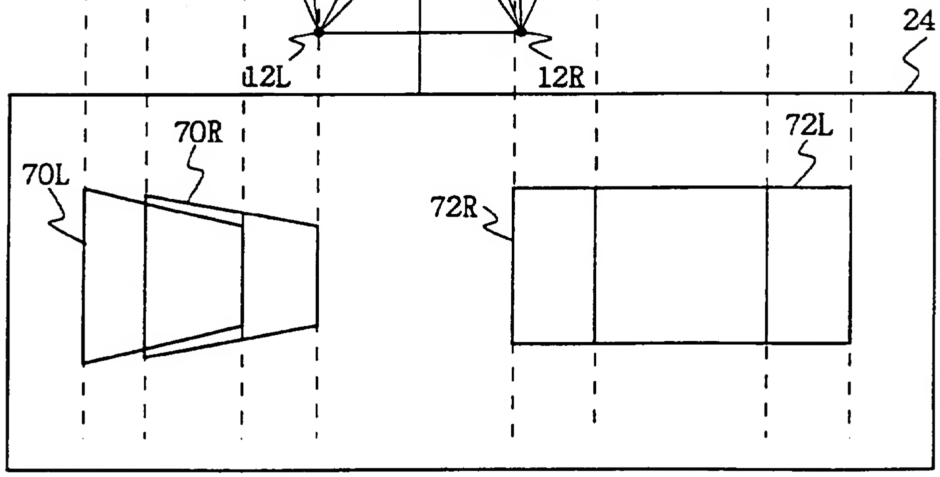


FIG. 8 (B)

Description of Reference Numerals

1... stereoscopic image displaying apparatus, 2L, 2R... left-eye and right-eye projectors, 3RR to 3LB... three primary color deflecting filters, 4... screen, 5... glasses, 6L, 6R... left eye and right eye, 7L, 7R... left-eye and right-eye images, 8L, 8R... the operator's eyes, 9B, 9F... imaged images, 11... screen, 12L, 12R... left eye and right eye, 13... imaged object's image, 14L, 14R... left-eye and right-eye images, 21... stereoscopic image generation apparatus, 22L, 22R... left-eye and right-eye processors, 23L, 23R... left-eye and right-eye projectors, 24... screen, 32... central processing unit (CPU), 33... program memory, 34... working memory, 35... write-in address generation circuit, 36L, 36R... frame memories, 37L, 37R... key signal memories, 38... screen address generation circuit, 39L, 39R... read-out address generation circuit, 40L, 40R... video signal interpolation circuits, 41L, 41R... combiners 42L, 42R... key signal interpolation circuits, 51... control panel, 61... stereoscopic image generation apparatus, 62L, 62R... left-eye and right-eye processors, 63L, 63R... left-eye and right-eye video signal recording devices, 64L, 64R... left-eye and right-eye switches, 65L and 65R... key signal generation circuits.

VERIFICATION OF TRANSLATION

I, Shigemoto Tanabe, a member of Tanabe Patent Office, of 11-11-508, Jingumae 1-chome, Shibuya-ku, Tokyo, Japan,

declare as follows:

1. That I am well acquainted with both the English and Japanese languages, and

2. That the attached document is a true and correct translation made by me to the best of my knowledge and belief of:-

   The specification accompanying the International Application No. PCT/JP96/03027 filed on 18 October 1996.

24 April 1997

Shigemoto Tanabe

Shigemoto Tanabe

DESCRIPTION

Title of the Invention

STEREOSCOPIC IMAGE GENERATION METHOD AND APPARATUS THEREOF

Technical Field

The present invention relates to a stereoscopic image generation method and apparatus thereof, which particularly will generate a stereoscopic image that the operator can perceive in a virtual space based on the video signal representing two-dimensional image.

Background Art

Hitherto, a stereoscopic image display apparatus as shown in Fig. 1 is proposed as a stereoscopic image generation apparatus which enables the operator to appreciate stereoscopic images.

The stereoscopic image display apparatus 1 is constructed so as to project left-eye projecting light and right-eye projecting light from a left-eye projector 2L and a right-eye projector 2R through each read, green, and blue three primary color deflecting filters 3LR, 3LG, 3LB, and 3RR, 3RG, 3RB on a screen 4 to display color composite image on the screen 4, so that the operator can see the color composite image through glasses 5 having a left-eye filter 5L and a right-eye filter 5R.

In this case, the operator sees the left-eye image out of the color composite image projected from the left-eye projector 2L through the left-eye filter 5L, and also sees the right-eye image

projected from the right-eye projector 2R through the right-eye filter 5R. As a result, as shown in Figs. 2(A) to 2(C), the operator perceives the color composite image on the screen 4 as a stereoscopic image based on visual difference between a left eye 6L and a right eye 6R.

Incidentally, as shown in Fig. 2(A), when a left-eye image 7L projected from the left-eye projector 2L and a right-eye image 7R projected from the right-eye projector 2R are displayed on the same position on the screen 4, 8L, the operator's left eye 6L, is crossed with 8R, the operator's right eye 6R, at the same point on the screen 4, so that the operator recognizes as if "there is a composite stereoscopic image on the screen 4."

On the contrary, as shown in Fig. 2(B), when the left-eye image 7L and the right-eye image 7R are displayed shifting with each other at the position opposite to the left eye 6L and the right eye 6R on the screen 4, a virtual image 9B is imaged at the point in the virtual space (it is generated backward than the screen 4) in which the operator's eye 8L seeing the left-eye image 7L by the his/her left eye 6L and the operator's eye 8R seeing the right-eye image 7R by the his/her right eye 6R are crossed. This makes the operator to recognize as if "there is a composite stereoscopic image backward the screen 4."

Further, as shown in Fig. 2(C), when the right-eye image 7R and the left-eye image 7L are projected at the position on the screen 4 opposite to the left eye 6L and the right eye 6R, the operator's eye 8L seeing the left-eye image 7L by the left eye 6L and the operator's eye 8R seeing the right-eye image 7R by the

right eye 6R are crossed at the forward position than the screen 4 in the virtual space, and a virtual image 9F is imaged. This makes the operator recognize as if "there is a composite stereoscopic image in front of the screen."

Consequently, since the projecting points of the left-eye image 7L and the right-eye image 7R on the screen 4 can be shifted by the distance corresponding to the visual difference between the left eye 6L and the right eye 6R, the operator can appreciate the composite stereoscopic image as if it were displayed at the position of the screen 4, or backward or front in the screen 4.

When generating a stereoscopic image by way of such method, however, it is very difficult actually to decide the projecting positions of the left-eye image 7L and the right-eye image 7R projected from the left-eye projector 2L and the right-eye projector 2R, which requires the operator well enough skill.

Incidentally, visual difference between the left eye 6L and the right eye 6R is actually not so large (3.25 [cm] and the like), so that actual generation of effective stereoscopic image requires the complicated setting operation that the skilled operator sets the projecting point of the left-eye image 7L and the right-eye image 7R by changing with trials and errors.

Disclosure of the Invention

The present invention has been made in view of the aforementioned points and proposes a stereoscopic image generation method and apparatus thereof which is capable of easily displaying the composite stereoscopic image of the left-eye image and the

right-eye image at desirable position on the screen as needed.

To solve the aforementioned problems, in the present invention, processes source video signal with the image conversion process by way of left-eye image conversion process means and right-eye image conversion process means, so that the left-eye image and the right-eye image can be generated at the desired position on the screen corresponding to the visual difference.

In order to obtain the left-eye image, the image conversion arithmetic operation for generating left-eye stereoscopic video signal from the source video signal is executed based on a spatial image conversion matrix for converting the image represented by the source video signal to a virtual spatial position and a left-eye perspective conversion matrix for having a converted image represented by a conversion video signal converted to the virtual spatial position seen through. Further, in order to obtain the right-eye image, the image conversion arithmetic operation for generating right-eye stereoscopic video signal from the source video signal is executed based on the spatial image conversion matrix and a right-eye perspective conversion matrix for having a converted image represented by a conversion video signal seen through.

Thus, according to the present invention, the left-eye and right-eye images can have the appropriate visual difference between each other by the parameter that the operator inputs based on the input video signal showing a two-dimensional image, so that it is possible to generate a stereoscopic image having much finer picture quality.

Further, according to the present invention, when the operator processes the desired three-dimensional process to the two-dimensional source video signal, use of the spatial conversion matrix and the left-eye perspective conversion matrix and the right-eye perspective conversion matrix can generate a left-eye and right-eye two-dimensional video signals having appropriate visual difference with each other easily by arithmetic operation based on the spatial position of the converted source video signal.

Further, the source video signal is moved continuously by frames in the three-dimensional space based on the operator's operation, the right-eye video signal and the left-eye video signal in real time interlocking with the continuous movement of the source video signal.

Further, the simultaneous image conversion process based on one input video signal at the time of generating the left-eye and right-eye images removes such complicated process as re-synchronization of the left-eye and right-eye images, which makes it possible to generate much better stereoscopic image. Accordingly, it is possible to display the left-eye video signal and the right-eye video signal synchronizing with each other all the time on the screen.

Brief Description of the Drawing

Fig. 1 is a perspective view showing a stereoscopic image display apparatus to which the present invention can be applied.

Figs. 2(A) to 2(C) are schematic diagrams explaining that the operator can perceive a stereoscopic image according to the

structure of Fig. 1.

Fig. 3 is a schematic diagram explaining the left-eye and right-eye images to be generated by the present invention.

Figs. 4(A1) to (B2) are schematic diagrams explaining the movement principle of the stereoscopic image generation apparatus and method thereof according to the present invention.

Fig. 5 is a schematic diagram explaining the image conversion process between positional vector on a frame memory and positional vector on the screen.

Fig. 6 is a block diagram showing the first embodiment of the stereoscopic image generation apparatus according to the present invention.

Fig. 7 is a block diagram showing the second embodiment of the stereoscopic image generation apparatus according to the present invention.

Figs. 8(A) and 8(B) are schematic diagrams explaining the operation of Fig. 7.

Best Mode for Carrying Out the Invention

Referring to the drawings, one embodiment of the present invention will be described in detail.

(1) Generation Principle of the Stereoscopic Image

A method of generating a stereoscopic image according to the present invention is as follows. As shown in Fig. 3, in xyz-virtual space including a screen 11, an image conversion arithmetic operation is executed so as to obtain left-eye and right-eye images 14L and 14R in which the image of an object 13 is

seen through on a screen 11 along the directions of left and right eyes 12L and 12R when the left eye 12L and the right eye 12R see the object 13, a composite stereoscopic image having depth, at an arbitrary position.

Here, the depth means the information representing the position in the direction along the centerline passing between the left eye 12L and the right eye 12R both watching the object 13.

As shown in Fig. 4(A1), an image V1 shown by an input video signal as a source video signal (referred to as an object) is set as the image displayed at the origin of xy-plane on the display screen of the screen 11 on x- and y-axes.

The object V1, the image of the input video signal input as the source video signal, is processed a parallel movement arithmetic operation and a rotary arithmetic operation by a three-dimensional image conversion matrix T_0 represented by the following equation:

$$T_0 = \begin{bmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & 0 \\ l_x & l_y & l_z & S_0 \end{bmatrix} \qquad \ldots (1)$$

so as to be converted to an intermediate conversion image V2.

The conversion process according to the three-dimensional image conversion matrix T_0 executes the image conversion arithmetic operation on the input video signal with the spatial image conversion matrix T_0, which makes the image of the object V1

represented by the input video signal move in parallel in the depth direction from the position on the x-y plane along z-axis on the screen 11 and rotate. As a result, the input video signal converted to the converted image having the depth information at backward position of the screen 11.

The intermediate conversion image V2 is converted for the image conversion representing visual difference from the left eye 12L by $+\Delta x$ movement matrix L represented by the following equation:

$$L = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \Delta x & 0 & 0 & 1 \end{bmatrix} \quad \ldots (2)$$

Consequently, an intermediate conversion image V3L is obtained.

The $+\Delta x$ movement matrix L means execution of the conversion arithmetic operation which moves the intermediate conversion image V2 in the direction along x-axis in parallel by the distance of $+\Delta x$. The left eye 12L is therefore assumed to be on z-axis and in the condition of seeing the intermediate conversion image V3L from its position 12LX.

Next, the intermediate conversion image VL3 is converted by using a see-through matrix P_0 represented by the following equation:

$$P_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \ldots (3)$$

As a result, an intermediate conversion image V4L is obtained on the screen 11 on x- and y-axes.

The conversion process by the see-through matrix P_0 means that, when the intermediate conversion image V3L is in the direction from the position 12LX of the left eye 12L, the intermediate conversion image V4L can be seen by having the see-through image of the intermediate conversion image V3L seen through on the screen 11.

Next, the intermediate conversion image V4L is converted by $-\Delta x$ movement matrix L^{-1} represented by the following equation:

$$L^{-1} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\Delta x & 0 & 0 & 1 \end{bmatrix} \quad \ldots (4)$$

As a result, it is converted to a final conversion image V5L.

$-\Delta x$ movement matrix L^{-1} moves the intermediate image V4L in the direction of x-axis in parallel by the distance of $-\Delta x$. Assuming z-axis to be the center between the left eye 12L and the right eye 12R, the position of the left eye 12L is moved by Δx from the center to left, so that the final conversion image V5L is

obtained as the see-through image on the screen 11 (Fig. 4(B1)) when the left eye 12L sees the intermediate conversion image V2 from the original position.

Since the intermediate conversion image V2 is deep, a left-eye image 14L shows a see-through image as the forward part of image seems to be bigger and the backward part of image seems to become smaller in the direction of depth.

The conversion parameter r_{11} to r_{33} used in the equation (1) rotates the input image V1 in the three-dimensional space of x-, y-, and z-axes. The parameter l_x, l_y, and l_z moves the input image V1 in parallel in the direction of x-, y-, and z-axes. The conversion parameter S0 enlarges and reduces the input image V1 two-dimensionally.

Further, the conversion parameter Δx, $-\Delta x$ used in the equations (2) and (4) moves the intermediate conversion image in parallel by the distance $+\Delta x$ and $-\Delta x$.

Further, the conversion parameter P_z used in the equation (3) is a perspective value for applying the perspective for having the intermediate conversion image V3L seen through on the screen 11, and is set to the value in which the value of the following equation:

$$P_z = -\frac{1}{16} \qquad \cdots (5)$$

is the reference value; it means that the operator's eyes are at the position of -16 on the z-axis.

The summary of the conversion processes of the left-eye image 14L shown in Fig. 4(A1) can be represented by the following equations.

More specifically, noticing a first conversion process step for converting the object V1 to the intermediate conversion image V2 by gain of the left-eye final conversion image V5L based on the object V1, the image of the input video signal, and a second conversion process step for converting so as to obtain the left-eye image 14L, the left-eye conversion matrix T_L can be represented by the following equation:

$$T_L = T_0 \; P_L \qquad \ldots (6)$$

which multiplies the conversion matrix T_0 according to the equation (1) by the conversion matrix T_L showing the conversion process thereafter.

Here, the conversion matrix P_L used at the second conversion process step is a perspective conversion matrix as shown in the following equation:

$$P_L = LP_0 \; L^{-1} \qquad \ldots (7)$$

By substituting the equations (2), (3), and (4) into the equation (7), the following equation:

$$P_L = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \Delta x & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\Delta x & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ -P_z\Delta x & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \ldots (8)$$

can be expressed.

Here, by substituting the equations (1) and (8) into the equation (6), the left-eye conversion matrix T_L can be expressed as follows:

$$T_L = \begin{bmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & 0 \\ l_x & l_y & l_z & S_0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ -P_z\Delta x & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} r_{11}-r_{13}P_z\Delta x & r_{12} & 0 & r_{13}P_z \\ r_{21}-r_{23}P_z\Delta x & r_{22} & 0 & r_{23}P_z \\ r_{13}-r_{33}P_z\Delta x & r_{32} & 0 & r_{33}P_z \\ l_x - l_z P_z\Delta x & l_y & 0 & l_zP_z+S_0 \end{bmatrix} \quad \ldots (9)$$

Incidentally in the conversion matrix T_L represented by the equation (9), after the image data is captured in the frame memory, the input video signal actually executes the conversion process by the parameter consisting the matrix. However, since both the data

read out from the frame memory and the image data displayed on the screen 11 are two-dimensional data, arithmetic operation for two-dimensional address does not need the parameters in the third line and third column of the equation (9).

Consequently, the conversion matrix T_{L33} represented by the following equation which omits the third line and the third column from the equation (9):

$$T_{L33} = \begin{bmatrix} r_{11} - r_{13}P_z\Delta x & r_{12} & r_{13}P_z \\ r_{12} - r_{23}P_z\Delta x & r_{22} & r_{23}P_z \\ l_x - l_z P_z\Delta x & l_y & l_zP_z + S_0 \end{bmatrix} \quad \ldots (10)$$

is used as the matrix for converting the position vector [x, y] on the frame memory to the position vector $[X_s, Y_s]$ on the screen 11.

Here, the conversion matrixes of four lines by four columns as shown in the equations (1) to (4) represent different dimensional conversions as the rotary conversion and enlargement/reduction in the same coordinate system, which makes the matrix of 4×4; this is generally called Homogeneous Coordinate.

When the two-dimensional position vector [x, y] on the frame memory and the two-dimensional position vector $[X_s, Y_s]$ on the screen 11 are represented in the Homogeneous Coordinate, [x, y] can be represented to [x, y, H] and $[X_s, Y_s]$ can be represented to $[X_s, Y_s, 1]$. H is the value showing an image enlargement ratio transformed by the perspective, which is proportioned to the value of the position vector in the direction of z-axis.

Operation of the conversion matrix T_{L33} to the position vector [x, y, H] on the frame memory can obtains the vector [X_s, Y_s, 1]. The obtained vector on the screen 11 is defined as follows:

$$[X_s \; Y_s \; 1] = [x \; y \; H] \; T_{L33} \qquad \ldots (11)$$

In this embodiment, however, when the spatial image conversion is executed, an address on the frame memory is specified to a screen address supplied sequentially corresponding to raster scanning as three-dimensional conversion at the time of reading out the input data from the frame memory.

More specifically, as shown in Fig. 5, when the inverse arithmetic operation as follows:

$$[x \; y \; H] = [X_s \; Y_s \; 1] \; T_{L33}^{-1} \qquad \ldots (12)$$

is executed, the designation of the position vector [x, y, H] of the corresponding frame memory is made corresponding to sequential designation of the position vector [X_s, Y_s, 1] on the screen 11 according to the raster scanning. Therefore, supply of the position vector [x, y, H] as the two-dimensional read-out address to the frame memory and the key memory provides the two-dimensional video data and key signal to which spatial image conversion is executed.

The inverse conversion matrix T_{L33}^{-1} of the equation (12) can be obtained as follows.

First, each element of the conversion matrix T_{L33} is set as

parameters a_{11} to a_{33} as follows:

$$T_{L33} = \begin{bmatrix} r_{11} - r_{13}P_z\Delta x & r_{12} & r_{13}P_z \\ r_{21} - r_{23}P_z\Delta x & r_{22} & r_{23}P_z \\ l_x - l_zP_z\Delta x & l_y & l_zP_z + S_0 \end{bmatrix} \quad \ldots (13)$$

$$= \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

Also, the parameters of the inverse matrix T_{L33}^{-1} are represented as parameters b_{11} to b_{33} as follows:

$$T_{L33}^{-1} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}^{-1} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \quad \ldots (14)$$

Substitution the equation (14) into the equation (12) can represent the following equation:

$$[x \ y \ H] = [X_s \ Y_s \ 1] \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \quad \ldots (15)$$

Above equation can be expanded to:

$$[x \ y \ H] = [b_{11}X_s + b_{12}Y_s + b_{13}$$

$$b_{21}X_s + b_{22}Y_s + b_{23}$$

$$b_{31}X_s + b_{32}Y_s + b_{33}] \qquad \ldots (16)$$

The following equations are thus derived from the equation (16):

$$x = b_{11}X_s + b_{12}Y_s + b_{13} \qquad \ldots (17)$$

$$y = b_{21}X_s + b_{22}Y_s + b_{23} \qquad \ldots (18)$$

$$H = b_{31}X_s + b_{32}Y_s + b_{33} \qquad \ldots (19)$$

by which the value of each element of the position vector (x, y, H) on the frame memory can be obtained.

The position vector [x, y, H] on the frame memory, however, is on the Homogeneous Coordinate. Normalization of the coordinate values x, y by the parameter H can restore it to the two-dimensional coordinate system.

Accordingly, the address $[X_{Im}, Y_{Im}]$ on the frame memory can be obtained as follows:

$$X_{Im} = \frac{x}{H} = \frac{b_{11}X_s + b_{12}Y_s + b_{13}}{b_{31}X_s + b_{32}Y_s + b_{33}} \qquad \ldots (20)$$

$$Y_{IM} = \frac{Y}{H}$$

$$= \frac{b_{21}X_s + b_{22}Y_s + b_{23}}{b_{31}X_s + b_{32}Y_s + b_{33}} \quad \ldots (21)$$

The data of the pixels corresponding to the screen address (X_s, Y_s) thus can be read out sequentially from the frame memory and the key information memory by using the address data X_{IM} and Y_{IM}.

In the equations (20) and (21), the values of B_{11} to b_{33} are obtained as follows from the equation (14):

$$b_{11} = \frac{-a_{32}a_{23} + a_{22}a_{33}}{W_1} \quad \ldots (22)$$

$$b_{12} = \frac{a_{32}a_{13} - a_{12}a_{33}}{W_1} \quad \ldots (23)$$

$$b_{13} = \frac{-a_{22}a_{13} + a_{12}a_{23}}{W_1} \quad \ldots (24)$$

$$b_{21} = \frac{a_{31}a_{23} - a_{21}a_{33}}{W_1} \quad \ldots (25)$$

$$b_{22} = \frac{-a_{31}a_{13} + a_{11}a_{33}}{W_1} \quad \ldots (26)$$

$$b_{23} = \frac{a_{21}a_{13} - a_{11}a_{23}}{W_1} \quad \text{... (27)}$$

$$b_{31} = \frac{- a_{22}a_{31} + a_{21}a_{32}}{W_1} \quad \text{... (28)}$$

$$b_{32} = \frac{a_{12}a_{31} - a_{11}a_{32}}{W_1} \quad \text{... (29)}$$

$$b_{33} = \frac{- a_{12}a_{21} + a_{11}a_{22}}{W_1} \quad \text{... (30)}$$

Provided that, it is:

$$W_1 = - a_{22}a_{31}a_{13} + a_{21}a_{32}a_{13} + a_{12}a_{31}a_{23} - a_{11}a_{32}a_{23} - a_{12}a_{21}a_{33} + a_{11}a_{22}a_{33} \quad \text{... (31)}$$

Here, the values of a_{11} to a_{33} are obtained as follows from the equation (13):

$$a_{11} = r_{11} - r_{13}P_z \Delta x, \quad a_{12} = r_{12}, \quad a_{13} = r_{13}P_z \quad \text{... (32)}$$

$$a_{21} = r_{21} - r_{23}P_z \Delta x, \quad a_{22} = r_{22}, \quad a_{23} = r_{23}P_z \quad \text{... (33)}$$

$$a_{31} = l_x - l_zP_z \Delta x, \quad a_{32} = l_y, \quad a_{33} = l_zP_z+S_0 \quad \text{... (34)}$$

Thus, substitution of the above values into the equations

(22) to (31) can expresses the following equations:

$$b_{11} = \frac{-l_y r_{23} P_z + r_{22}(l_z P_z + S_0)}{W_1} \quad \ldots (35)$$

$$b_{12} = \frac{l_y r_{13} P_z + r_{12}(l_z P_z + S_0)}{W_1} \quad \ldots (36)$$

$$b_{13} = \frac{-r_{22} r_{13} P_z + r_{12} r_{23} P_z}{W_1} \quad \ldots (37)$$

$$b_{21} = \frac{(l_x - l_z P_z \Delta x) r_{23} P_z - (r_{21} - r_{23} P_z \Delta x)(l_z P_z + S_0)}{W_1} \quad \ldots (38)$$

$$b_{22} = \frac{-(l_x - l_z P_z \Delta x) r_{13} P_z + (r_{11} - r_{13} P_z \Delta x)(l_z P_z + S_0)}{W_1} \quad \ldots (39)$$

$$b_{23} = \frac{(r_{21} - r_{23} P_z \Delta x) r_{13} P_z - (r_{11} - r_{13} P_z \Delta x) r_{23} P_z}{W_1} \quad \ldots (40)$$

$$b_{31} = \frac{-r_{22}(l_x - l_z P_z \Delta x) + (r_{21} - r_{23} P_z \Delta x) l_y}{W_1} \quad \ldots (41)$$

$$b_{32} = \frac{r_{12}(l_x - l_z P_z \Delta x) - (r_{11} - r_{13} P_z \Delta x) l_y}{W_1} \quad \ldots (42)$$

$$b_{33} = \frac{-r_{12}(r_{21} - r_{23}P_z\Delta x) + (r_{11} - r_{13}P_z\Delta x)r_{22}}{W_1} \quad \ldots (43)$$

$$\begin{aligned} W_1 = & -r_{22}(l_x - l_zP_z \Delta x)r_{13}P_z \\ & + (r_{21}-r_{23}P_z \Delta x)l_yr_{13}P_z \\ & + r_{12}(l_x - l_zP_z \Delta x)r_{23}P_z \\ & - (r_{11}-r_{13}P_z \Delta x)l_yr_{23}P_z \\ & - r_{12}(r_{21}-r_{23}P_z \Delta x)(l_zP_z+S_0) \\ & + (r_{11}-r_{13}P_z \Delta x)r_{22}(l_zP_z+S_0) \quad \ldots (44) \end{aligned}$$

by using the parameters set by the operator in the conversion matrixes represented in the equations (1) to (4).

Thus substitution of the values obtained in the equations (35) to (44) into the equations (20) and (21) supplies the read-out address (X_{LM}, Y_{LM}) as follows to the frame memory:

$$\begin{aligned} X_{Lm} = & \frac{1}{H}[\{-l_xr_{23}P_z + r_{22}(l_zP_z + S_0)\} X_s \\ & + \{l_yr_{13}P_z + r_{12}(l_zP_z + S_0)\} Y_s \\ & + (-r_{22}r_{13}P_z + r_{12}r_{23}P_z)] \quad \ldots (45) \end{aligned}$$

$$\begin{aligned} Y_{Lm} = & \frac{1}{H}[\{(l_x - l_zP_z\Delta x) r_{23}P_z \\ & - (r_{21}-r_{23}P_z \Delta x)(l_zP_z + S_0)\} X_s \\ & + \{-(l_x-l_zP_z \Delta x\ r_{13}P_z \\ & + (r_{11}-r_{13}P_z \Delta x)(l_zP_z + S_0)\} Y_s \\ & + \{r_{21}-r_{23}P_z \Delta x)\ r_{13}P_z \end{aligned}$$

$$- (r_{11}-r_{13}P_z \Delta x) \ r_{23}P_z\}] \qquad \ldots (46)$$

Here, it is as follows:

$$H = \{-r_{22}(l_x-l_zP_z \Delta x) + (r_{21} - r_{23}P_z \Delta x) l_y\} \ X_S$$
$$+ \{r_{12}(l_x-l_zP_z \Delta x) - (r_{11} - r_{13}P_z \Delta x) l_y\} \ Y_S$$
$$+ \{-r_{12}(r_{21}-r_{23}P_z \Delta x) + (r_{11} - r_{13}P_z \Delta x) r_{22}\} \qquad \ldots (47)$$

The processes described above are the arithmetic operations for the left-eye image conversion to the object V1 shown in Fig. 4(A1). The arithmetic operations for the right-eye image conversion is also executed corresponding to the arithmetic operations for the left-eye image conversion as shown in Fig. 4(A2).

More specifically, the three-dimensional conversion matrix T_0 moves the object V1 input as an image of the input video signal at the origin of x-y plane on the screen 11 in parallel in the depth direction on z-axis, and then rotates it to convert to an intermediate conversion image V2.

Then, as the conversion process for representing the visual difference of the right eye to the intermediate conversion image V2, parallel movement by $-\Delta x$ movement matrix L^{-1} represented by the equation (4) in the parallel direction of x-axis by the distance of $-\Delta x$ converts the intermediate conversion image V2 to an intermediate conversion image V3.

Then, conversion of the intermediate conversion image V3R by the see-through matrix P_0 represented by the equation (3) provides

an intermediate conversion image V4R in which the intermediate conversion image V3R has been seen through on the screen 11. The intermediate conversion image V4R means that, when being at the position 12RX on the z-axis, the right eye 12R obtains the image V4R in which the intermediate conversion image V2 is seen through on the screen 11 in the direction of the right eye 12R.

The intermediate conversion image V4R is represented by the equation (2). Being converted by the movement matrix L, the image V4R is moved in parallel in the direction of x-axis by the distance of $+\Delta x$, and then is converted to an final intermediate conversion image V5R.

This right-eye final intermediate image V5R is the image in which the intermediate conversion image V2 has seen through on the screen 11 in the original direction of the right eye 12R when the right eye 12R at the original position shifted from the center on the z-axis (the center between the left eye 12L and the right eye 12R) in right direction by Δx sees the intermediate conversion image V2.

The operator can thus see the right-eye final conversion image V5R as the deep right-eye image 14R on the x-y plane executed the process based on the perspective, in which the front image portion is bigger and the image portion in depth direction becomes smaller.

The conversion process for converting the object V1 based on the input video signal to the right-eye final conversion image V5R, as shown in Fig. 4(B1), is executed as follows similarly to the left-eye conversion process.

More specifically, the following conversion matrix T_R on the arithmetic operation for the right eye is as follows:

$$T_R = T_0 \ P_R \qquad \ldots (48)$$

which can be regarded that there are two parts; the three-dimensional conversion matrix T_0 which moves and rotary converts the object V1 on z-axis, and the conversion matrix P_R which executes the conversion process thereafter. The right-eye conversion matrix P_R is represented by the $-\Delta x$ parallel movement matrix L^{-1} of the equation (4), the see-through matrix P_0 of the equation (3), and $+\Delta x$ movement matrix L of the equation (2) as follows:

$$P_R = L^{-1} \ P_0 \ L \qquad \ldots (49)$$

Substitution of the equations (4), (3) and (2) into the equation (49) realizes the expansion as follows:

$$P_R = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\Delta x & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \Delta x & 0 & 0 & 1 \end{bmatrix} \qquad \ldots (50)$$
$$= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ P_z\Delta x & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

If the equation (50) is substituted into the equation (48), the conversion matrix P_R for executing the right-eye spatial image conversion can be expanded as follows:

$$P_R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & 0 \\ l_x & l_y & l_z & S_0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ P_z\Delta x & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} r_{11} + r_{13}P_z\Delta x & r_{12} & 0 & r_{13}P_z \\ r_{21} + r_{23}P_z\Delta x & r_{22} & 0 & r_{23}P_z \\ r_{31} + r_{33}P_z\Delta x & r_{32} & 0 & r_{33}P_z \\ l_x + l_zP_z\Delta x & l_y & 0 & l_zP_z + S_0 \end{bmatrix} \quad \ldots (51)$$

In order to obtain significant information of only the x-y plane, the right-eye conversion matrix T_{R33} which is represented by omission of the third line and third column of the equation (51) as the following equation:

$$T_{R33} = \begin{bmatrix} r_{11} + r_{13}P_z\Delta x & r_{12} & r_{13}P_z \\ r_{12} + r_{23}P_z\Delta x & r_{22} & r_{23}P_z \\ l_x + l_zP_z\Delta x & l_y & l_zP_z + S_0 \end{bmatrix} \quad \ldots (52)$$

is used.

Also the right-eye conversion process can obtain the vector $[X_S\ Y_S\ 1]$ on the screen 11 by operating the conversion matrix T_{R33} to the position vector $[x\ y\ H]$ on the frame memory as mentioned above with regard to Fig. 5. The vector on the screen 11 thus

defined by the following equation:

$$[X_S\ Y_S\ 1] = [x\ y\ H]T_{R33} \qquad \ldots (53)$$

Then, in order to obtain the read-out address used for reading out video data from the frame memory, the above equation is inversely calculated as follows:

$$[x\ y\ H] = [X_S\ Y_S\ 1]T_{L33}^{-1} \qquad \ldots (54)$$

This enables to specify the position vector [x y H] of the frame memory corresponding to the position vector $[X_S\ Y_S\ 1]$ on the screen 11 when the position vector $[X_S\ Y_S\ 1]$ is specified according to raster scanning. It is thus possible to obtain the two-dimensional video data and key signal spatially converted the image.

Here, in order to obtain the inverse conversion matrix T_{L33}^{-1}, the parameters a_{11} to a_{33} and b_{11} to b_{33} are set as elements for the conversion matrix T_{R33} and the inverse conversion matrix T_{R33}^{-1} as follows:

$$T_{R33} = \begin{bmatrix} r_{11} + r_{13}P_z\Delta x & r_{12} & r_{13}P_z \\ r_{21} + r_{23}P_z\Delta x & r_{22} & r_{23}P_z \\ l_x + l_zP_z\Delta x & l_y & l_zP_z + S_0 \end{bmatrix}$$

$$= \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \qquad \ldots (55)$$

$$T_{R33}^{-1} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}^{-1} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \qquad \ldots (56)$$

Those equations permits to obtain the parameters b_{11} to b_{33} as follows:

$$b_{11} = \frac{-a_{32}a_{23} + a_{22}a_{33}}{W_1} \qquad \ldots (57)$$

$$b_{12} = \frac{a_{32}a_{13} - a_{12}a_{33}}{W_1} \qquad \ldots (58)$$

$$b_{13} = \frac{-a_{22}a_{13} + a_{12}a_{23}}{W_1} \qquad \ldots (59)$$

$$b_{21} = \frac{a_{31}a_{23} - a_{21}a_{33}}{W_1} \qquad \ldots (60)$$

$$b_{22} = \frac{-a_{31}a_{13} + a_{11}a_{33}}{W_1} \qquad \ldots (61)$$

$$b_{23} = \frac{a_{21}a_{13} - a_{11}a_{23}}{W_1} \qquad \ldots (62)$$

$$b_{31} = \frac{-a_{22}a_{31} + a_{21}a_{32}}{W_1} \quad \ldots (63)$$

$$b_{32} = \frac{a_{12}a_{31} - a_{11}a_{32}}{W_1} \quad \ldots (64)$$

$$b_{33} = \frac{-a_{12}a_{21} + a_{11}a_{22}}{W_1} \quad \ldots (65)$$

here, it is as follows:

$$W_1 = -a_{22}a_{31}a_{13} + a_{21}a_{32}a_{13} + a_{12}a_{31}a_{23} - a_{11}a_{32}a_{23} - a_{12}a_{21}a_{33} + a_{11}a_{22}a_{33} \quad \ldots (66)$$

The parameters a_{11} to a_{33} are obtained from the equation (55) as follows:

$$a_{11} = r_{11} + r_{13}P_z \Delta x, \quad a_{12} = r_{12}, \quad a_{13} = r_{13}P_z \quad \ldots (67)$$

$$a_{21} = r_{21} + r_{23}P_z \Delta x, \quad a_{22} = r_{22}, \quad a_{23} = r_{23}P_z \quad \ldots (68)$$

$$a_{31} = l_x + l_zP_z \Delta x, \quad a_{32} = l_y, \quad a_{33} = l_zP_z + S_0 \quad \ldots (69)$$

By substituting those equations into the equations (57) to (66) as follows:

$$b_{11} = \frac{-l_y r_{23} P_z + r_{22}(l_z P_z + S_0)}{W_1} \qquad \ldots (70)$$

$$b_{12} = \frac{l_y r_{13} P_z + r_{12}(l_z P_z + S_0)}{W_1} \qquad \ldots (71)$$

$$b_{13} = \frac{-r_{22} r_{13} P_z + r_{12} r_{23} P_z}{W_1} \qquad \ldots (72)$$

$$b_{21} = \frac{(l_x + l_z P_z \Delta x) r_{23} P_z - (r_{21} + r_{23} P_z \Delta x)(l_z P_z + S_0)}{W_1} \qquad \ldots (73)$$

$$b_{22} = \frac{-(l_x + l_z P_z \Delta x) r_{13} P_z + (r_{11} + r_{13} P_z \Delta x)(l_z P_z + S_0)}{W_1} \qquad \ldots (74)$$

$$b_{23} = \frac{(r_{21} + r_{23} P_z \Delta x) r_{13} P_z - (r_{11} + r_{13} P_z \Delta x) r_{23} P_z}{W_1} \qquad \ldots (75)$$

$$b_{31} = \frac{-r_{22}(l_x + l_z P_z \Delta x) + (r_{21} + r_{23} P_z \Delta x) l_y}{W_1} \qquad \ldots (76)$$

$$b_{32} = \frac{r_{12}(l_x + l_z P_z \Delta x) - (r_{11} + r_{13} P_z \Delta x) l_y}{W_1} \qquad \ldots (77)$$

$$b_{33} = \frac{-r_{12}(r_{21} + r_{23} P_z \Delta x) + (r_{11} + r_{13} P_z \Delta x) r_{22}}{W_1} \qquad \ldots (78)$$

$$
\begin{aligned}
W_1 = & -r_{22}(l_x + l_z P_z \Delta x) r_{13} P_z \\
& + (r_{21} + r_{23} P_z \Delta x) l_y r_{13} P_z \\
& + r_{12}(l_x + l_z P_z \Delta x) r_{23} P_z \\
& - (r_{11} + r_{13} P_z \Delta x) l_y r_{23} P_z \\
& - r_{12}(r_{21} + r_{23} P_z \Delta x)(l_z P_z + S_0) \\
& + (r_{11} + r_{13} P_z \Delta x) r_{22}(l_z P_z + S_0) \qquad \ldots (79)
\end{aligned}
$$

the values of each element in the matrix can be represented by the parameter in which the operator sets as the conversion condition as the equations (1) to (4).

Incidentally, same manner as the above-mentioned equations (15) to (21) can be applied to the right-eye conversion arithmetic operation. Substitution of relation of the equation (54) into the equation (56) can represent the following equation:

$$
[x \ y \ H] = [X_s \ Y_s \ 1] \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \qquad \ldots (80)
$$

which shows the position vector [x y H] by the position vector [X_s Y_s 1] and the parameters b_{11} to b_{13}. Then, expansion of this equation as follows:

$$
\begin{aligned}
[x \ y \ H] = [& b_{11} X_s + b_{12} Y_s + b_{13} \\
& b_{21} X_s + b_{22} Y_s + b_{23} \\
& b_{31} X_s + b_{32} Y_s + b_{33}] \qquad \ldots (81)
\end{aligned}
$$

can deduce the position vector [x y H] on the frame memory as follows:

$$x = b_{11}X_s + b_{12}Y_s + b_{13} \qquad \ldots (82)$$

$$y = b_{21}X_s + b_{22}Y_s + b_{23} \qquad \ldots (83)$$

$$H = b_{31}X_s + b_{32}Y_s + b_{33} \qquad \ldots (84)$$

Since the position vector [x y H] on the frame memory is the homogeneous coordinate, normalization by the parameter H can deduce the address (X_{Rm} Y_{Rm}) on the frame memory as follows:

$$X_{Rm} = \frac{x}{H} = \frac{b_{11}X_s + b_{12}Y_s + b_{13}}{b_{31}X_s + b_{32}Y_s + b_{33}} \qquad \ldots (85)$$

$$Y_{Rm} = \frac{y}{H} = \frac{b_{21}X_s + b_{22}Y_s + b_{23}}{b_{31}X_s + b_{32}Y_s + b_{33}} \qquad \ldots (86)$$

Then, by substituting the equations (70) to (79) into the equations (85) and (86), the read-out address (X_{Rm} Y_{Rm}) to the frame memory can be set as follows:

$$X_{Rm} = \frac{1}{H}[\{-l_x r_{23} P_z + r_{22}(l_z P_z + S_0)\} X_s$$

$$+ \{l_y r_{13} P_z + r_{12}(l_z P_z + S_0)\} Y_s$$

$$+ (-r_{22} r_{13} P_z + r_{12} r_{23} P_z)] \qquad \ldots (87)$$

$$Y_{Rm} = \frac{1}{H}[\{(l_x + l_z P_z \Delta x) r_{23} P_z$$

$$- (r_{21} + r_{23} P_z \Delta x)(l_z P_z + S_0)\} X_s$$

$$+ \{-(l_x + l_z P_z \Delta x \; r_{13} P_z$$

$$+ (r_{11} + r_{13} P_z \Delta x)(l_z P_z + S_0)\} Y_s$$

$$+ \{r_{21} + r_{23} P_z \Delta x) \; r_{13} P_z$$

$$- (r_{11} + r_{13} P_z \Delta x) \; r_{23} P_z\}] \qquad \ldots (88)$$

Here, it is as follows:

$$H = \{-r_{22}(l_x + l_z P_z \Delta x) + (r_{12} + r_{23} P_z \Delta x) \cdot l_y\} X_s$$

$$+ \{r_{12}(l_x + l_z P_z \Delta x) - (r_{11} + r_{13} P_z \Delta x) \cdot l_y\} Y_s$$

$$+ \{-r_{12} \cdot (r_{21} + r_{23} P_z \Delta x) + (r_{11} + r_{13} P_z \Delta x) r_{22}\} \qquad \ldots (89)$$

According to the stereoscopic image generation method described above, the intermediate conversion images V3L and V3R both of which the object V1 shown by the input video signal is moved and rotated in the depth direction and also moved in Δx and $-\Delta x$ directions are seen through on the screen 11 in the direction along the operators' left eye 12L and right eye 12R. Thereby the final conversion images V5L and V5R to be projected can be obtained by visual difference between the left eye 12L and the

right eye 12R. This enables to generate the deep image of the object on the screen, or backward the screen, or front in the screen based on the visual difference between the left eye 12L and the right eye 12R.

Then, the operator inputs each parameter of the three-dimensional conversion matrix T_0 defined by the equation (1), $+\Delta x$ movement matrix L defined by the equation (2), the see-through matrix P_0 defined by the equation (3), and $-\Delta x$ movement matrix L^{-1} defined by the equation (4), so that it is possible to generate stereoscopic image having arbitrary conversion correspondence at arbitrary position as necessary.

According to the processes described above, it is possible to arbitrarily select the parameters in which the operator can set such as r_{11} to r_{33} representing spatial rotation of the converted image, l_x, l_y and l_z representing parallel movements in the directions of x, y and z-axes, S_0 representing two-dimensional expansion/reduction, P_z representing the perspective value based on the perspective, and the value Δx representing a half of distance between the left eye 12L and the right eye 12R if the occasion demand. The image to be generated thus can be specified easily.

Further, the image data representing the image of the input video signal is written in and its read-out address is specified corresponding to the raster scan address on the screen. This enables to generate the left-eye and right-eye final conversion images V5L and V5R on the screen 11 at the same time.

(2) First Embodiment of the Stereoscopic Image Generation

Apparatus

In Fig. 6, 21 entirely shows a stereoscopic image generation apparatus, which receives an input video signal V_A, an input key signal K_A, and an input background signal V_{BK} at a left-eye processor 22L and a right-eye processor 22R, and supplies a left-eye and right-eye stereoscopic image output signals VL_{OUT} and VR_{Out} respectively representing the left-eye and right-eye final conversion images V5L and V5R to a left-eye and right-eye projectors 23L and 23R.

This permits the left-eye and right-eye projector 23L and 23R to project the left-eye and right-eye final conversion image V5L and V5R on a screen 24 respectively.

The left-eye processor 22L and the right-eye processor 22R, and the left-eye and right-eye projectors 23L and 23R are controlled by a central process unit (CPU) 32 via a bus 31.

According to a program in a program memory 33 having ROM structure, the CPU 32 utilizes a working memory 34 having RAM structure to execute process operation of each part in the stereoscopic image generation apparatus 21.

The CPU 32 generates write-in address signals Sx and Sy representing position vector [x y] on the frame memory at a write-in address generation circuit 35. The write-in address signals Sx and Sy sequentially specify storing position in frame memories 36L and 36R of the left-eye and right-eye processors 22L and 22R so as to store the input video signal V_A as left-eye and right-eye source video data synchronizing with each other.

The write-in address signals Sx and Sy are also supplied to

key signal memories 37L and 37R of the left-eye and right-eye processors 22L and 22R. This enables the key signal memories 37L and 37R to store the key data in regard to the position vector [x y] on the frame memories synchronizing with the input video signal V_A.

The CPU 32 drives a screen address generation circuit 38 provided for common use of the left-eye and right-eye processors 22L and 22R so as to generate the position vector [X_S Y_S] on the screen 24 based on a reference signal generated from a built-in reference signal generation circuit. These screen addresses SX_S and SY_S are supplied to read-out address generation circuits 39L and 39R of the left-eye and right-eye processors 22L and 22R.

The read-out address generation circuits 39L and 39R are under the control of the CPU 32 so as to supply read-out address signal SX_{Lm}, SY_{Lm} and SX_{Rm}, SY_{Rm} representing read-out addresses (X_{Lm} Y_{Lm}) and (X_{Rm} Y_{Rm}), which are respectively specified by the equations (45), (46) and (87) and (88), to the frame memories 36L and 36R and the key data memories 37L and 37R.

Image data VL_1 and VR_1 read out from the frame memories 36L and 36R of the left-eye and right-eye processors 22L and 22R are interpolated at video signal interpolation circuits 40L and 40R, and then are supplied to combiners 41L and 41R as read-out video signals VL_2 and VR_2.

At the same time, key data KL_1 and KR_1 read out from the key signal memories 37 and 37R of the left-eye and right-eye processors 22L and 22R are interpolated at the key signal interpolation circuits 40L and 40R, and then are supplied to the

combiners 42L and 42R as read-out video signal KL_2 and KR_2.

The combiners 41L and 41R are under the control of the CPU 32 so as to execute the keying process between the read-out video signals VL_2 and VR_2 and the input background signal V_{BK} by the read-out key signals KL_2 and KR_2. The combiners 41L and 41R consequently supply the stereoscopic image output signals VL_{out} and VR_{out} represented by the following equations:

$$VL_{out} = KL_2\ VL_2 + (1-KL_2)V_{BK} \qquad \ldots (90)$$

$$VR_{out} = KR_2\ VR_2 + (1-KR_2)V_{BK} \qquad \ldots (91)$$

as the output from the left-eye and right-eye processors 22L and 22R to the left-eye and right-eye projectors 23L and 23R.

The following description will be made of operation of the stereoscopic image generation apparatus 21.

First, the operator previously inputs the values of visual difference distance Δx and perspective value P_z necessary to the arithmetic operation of the present invention via a control panel 51. The CPU 32 stores the visual difference distance Δx and the perspective value P_z newly set by the operator in the RAM 34. Incidentally, when detecting no input from the operator, the CPU 32 uses the reference value (Δx = 3.25cm, $P_z = -1/16$) stored already in the RAM 34.

Then the operator operates a three-dimensional pointing device provided on the control panel 51 to command three-dimensional image conversion operation to source video signal.

When the operator commands the three-dimensional conversion process to the source video signal, the CPU 32 receives r_{11} to r_{33}, l_x, l_y, l_z and S_0 which are parameters of matrix T_0 showing the three-dimensional conversion specified by the operator. At the same time, the CPU 32 receives the visual difference distance Δx and the perspective value P_z stored in the RAM 34. Then, the CPU 32 utilizes the received parameters r_{11} to r_{33}, l_x, l_y, l_z and S_0, Δx and P_z so as to calculate the parameters b_{11} to b_{33} represented in the equations (35) to (43) and the parameters b_{11} to b_{33} represented in the equations (70) to (78). The CPU 32 supplies the calculated values of the parameter b_{11} to b_{33} to the read-out address generation circuit 39L; simultaneously supplies the calculated values of the parameter b_{11} to b_{33} to the read-out address generation circuit 39R.

The read-out address generation circuit 39L generates the left-eye read-out address (X_{Lm}, Y_{Lm}) represented in the equation (20) based on the parameters r_{11} to r_{33} supplied from the CPU 32 and the screen address (X_S, Y_S) supplied from the screen address generation circuit 38. The read-out address generation circuit 39L supplies the left-eye read-out address (X_{Lm}, Y_{Lm}) to the frame memory 36L and the key signal memory 37L.

At the same time, the read-out address generation circuit 39R generates the right-eye read-out address (X_{Rm}, Y_{Rm}) represented in the equation (85) based on the parameters b_{11} to b_{33} supplied from the CPU 32 and the screen address (X_{Lm}, Y_{Lm}) supplied from the screen address generation circuit 38. The read-out address generation circuit 39R supplies the right-eye read-out address $(X_{Rm},$

Y_{Rm}) to the frame memory 36R and the key signal memory 37R.

As described above, the conversion video signal VL_1 read out from the frame memory 36L represents the video signal V5L which is projected on the screen surface when the operator sees the video signal V2 converted in the three-dimensional space by the spatial conversion matrix T_0 from the position of the left eye 12L, as shown in Fig. 4(A1): the conversion video signal VR_1 read out from the frame memory 36R represents the video signal V5R which is projected on the screen surface when the operator sees the video signal V2 converted in the three-dimensional space by the spatial conversion matrix T_0 from the position of the right eye 12R, as shown in Fig. 4(A2).

The conversion video signals VL_1 and VR_1 read out from the frame memories 36L and 36R are interpolated at the video signal interpolation circuits 40L and 40R with peripheral pixels, and then are output as the conversion video signals VL_2 and VR_2. The conversion key signal KL_1 and KR_1 read out from the key signal memories 37L and 37R are similarly interpolated at the key signal interpolation circuits 42L and 42R with peripheral pixels, and then are output as the conversion key signal KL_2 and KR_2.

As described above, capture of the input information input by the operator with the control panel 51 through an interface 52 enables the CPU 32 to provide the left-eye and right-eye projectors 23L and 23R with the left-eye and right-eye stereoscopic image output signal VL_{out} and VR_{out}, which are generated by converting the input video signal V_A and the input key signal K_A at the same time according to the contents of image

conversion process specified by the operator, from the left-eye and right-eye processors 22L and 22R.

Here, if the operator sets the parameters r_{11} to r_{33} with the control panel 51, the CPU 32 specifies what degree the object V1 should rotate spatially in regard to the three-dimensional conversion matrix P_0 at the read-out address generation circuits 39L and 39R.

Further, if the operator sets the parameters l_x, l_y and l_z with the control panel 51, the CPU 32 specifies how far the object V1 should move in parallel in the direction of x-axis, y-axis and z-axis in regard to the three-dimensional conversion matrix P_0 at the read-out address generation circuits 39L and 39R.

Further, if the operator sets the parameter S_0 with the control panel 51, the CPU 32 specifies how large or small the object V1 should be extended or reduced on the xy plane in regard to the three-dimensional conversion matrix P_0 at the read-out address generation circuits 39L and 39R.

Further, if the operator sets the parameter Δx with the control panel 51, the CPU 32 generates the read-out address signals SX_{Lm}, SY_{Lm} and SX_{Rm}, SY_{Rm} which regulate how far the distance Δx, the half of the distance between the left eye 12L and the right eye 12R, should be in regard to the $+\Delta x$ movement matrix L and $-\Delta x$ movement matrix L^{-1}, namely how far visual difference between the left eye 12L and the right eye 12R should be.

In this embodiment, the parameter P_z is structured so that the value is input as 1/16 all the time from the control panel 51. The CPU 32 thus outputs the read-out address signal for regulating the

perspective value based on perspective for the see-through matrix P_0 at the read-out address generation circuits 39L and 39R.

The operator therefore can set the parameter Δx for regulating the visual difference between the left eye 12L and the right eye 12R on desired value by the control panel 51. This enables to set easily the amount of shift of the left-eye image 14L and the right-eye image 14R consisting of the final converted images V5L and V5R, which are projected on the screen 24 by the left-eye and right-eye projectors 23L and 23R, on the appropriate value at will.

As described above, the read-out address generation circuits 39L and 39R of the left-eye and right-eye processors 22L and 22R execute their processes at the same time based on common screen address signals SX_s and SY_s, so that the left-eye and right-eye stereoscopic image output signals VL_{out} and VR_{out} are generated simultaneously. This provides the stereoscopic image having better picture quality.

According to the structure described above, the left-eye perspective conversion matrix P_L and the right-eye perspective conversion matrix are utilized in the arithmetic operation of the left-eye video signal and the right-eye video signal in which the conversion video signal converted to the spatial position by moving and rotating the source video signal V1 in the three-dimensional space is projected on the xy-plane from the position of the left eye 12L and the position of the right eye 12R respectively. The appropriate video signal according to the visual difference between the left eye and the right eye therefore can be

generated.

Further, it is possible to generate the left-eye video signal and the right-eye video signal both of which have the visual difference according to the spatial position of the converted video signal V2. In other words, such arithmetic operation is executed as the more the source video signal is converted to the position of the depth direction (direction of +z) three-dimensionally to the screen, the more the left-eye video signal shifts to left and the right-eye video signal shifts to right. Further, such arithmetic operation is also executed as the source video signal is converted to the position of the front direction (direction of -z) three-dimensionally to the screen in contrast with the above, the more the left-eye video signal shifts to right and the right-eye video signal shifts to left. This enables to generate stereoscopic video signal easily.

(3) The Second Embodiment of the Stereoscopic Image Generation Apparatus

Fig. 7 shows the second embodiment of the present invention in which the same number is applied to the corresponding part of the stereoscopic image generation apparatus 61 in Fig. 6. The left-eye and right-eye stereoscopic image output signals VL_{OUT} and VR_{OUR} obtained from left-eye and right-eye projectors 62L and 62R are output to the left-eye and right-eye projectors 23L and 23R respectively and recorded in left-eye and right-eye video signal recording devices 63L and 63R consisting of, for example, video tape recorders.

The left-eye and right-eye video signal recording devices 63L and 67R are controlled by the CPU 32 so as to reproduce the recorded video signal as left-eye and right-eye feedback video signals VBL and VBR and feedback them to the frame memories 36L and 36R of the left-eye and right-eye processors 62L and 62R as image input signals VL_0 and VR_0 through switching input terminal W2 of switches 64L and 64R.

In this embodiment, the input video signal V_A is input to the frame memories 36L and 36R as input video signals WL_0 and WR_0 through two first switch terminals W1 of the left-eye and right-eye switches 64L and 64R both of which execute switching operations controlled by the CPU 32.

The input video signals VL_0 and VR_0 input through the left-eye and right-eye switches 64L and 64R are also input to key signal generation circuits 65L and 65R of the left-eye and right-eye processors 62L and 62R. Thus the CPU 32 controls to input input key signals KL_0 and KR_0 capable of keying process synchronized with the input video signals VL_0 and VR_0 from the key signal generation circuits 65L and 65R both of which execute the key signal generation operations to the key signal memories 37L and 37R.

With the structure of Fig. 7, as shown in Figs. 8(A) and 8(B), the first left-eye and right-eye images 70L and 70R out of images projected on the screen 24 from the left-eye and right-eye projectors 23L and 23R are projected on part of the screen 24, for instance the left part, and the second left-eye and right-eye images 72L and 72R are projected on the other part of the screen 24, for instance the right part.

The first left-eye and right-eye images 70L and 70R convert the image represented by the input video signal V_A with the image conversion method described above referring to Figs. 4(A1) to (B2).

In this embodiment, the operator recognizes the first left-eye and right-eye images 70L and 70R as a stereoscopic image 71 formed based on the input video signal V_A by seeing virtual image with the operator's left and right eyes 12L and 12R.

On the other hand, the second left-eye and right-eye images 72L and 72R projected on the right part of the screen 24 are such images as the images represented by the left-eye and right-eye feedback video signals VBL and VBR reproduced from the left-eye and right-eye video signal recording devices 63L and 63R are read out from the video memories 36L and 36R with the read-out address signals SX_{Lm}, SY_{Lm} and SX_{Rm}, SY_{Rm}, which are executed the image conversion process with the image conversion method described above according to Figs. 4(A1) to 4(B2), and then projected on the screen 24.

In the case of Fig. 8(A), the operator's left eye 12L and right eye 12R toward the second left-eye and right-eye images 72L and 72R intersects with each other in front of the screen 24. This enables the operator to recognize a stereoscopic image 73 formed by the left-eye and right-eye feedback video signals VBL and VBR in the virtual space in front of the screen 24.

With the structure shown in Fig. 7, the left-eye and right-eye switches 64L and 64R are controlled by the CPU 32 so as to let the video signal V_A through the first switch input terminals W1 at the timing of left portion out of the image section for one frame.

The video signal V_A is then stored in the left memory area of the left-eye and right-eye frame memories 36L and 36R.

On the other hand, the left-eye and right-eye switches 64L and 64R switch to the second switch input terminals W2 in the term of left portion out of the term for one frame, so that the left-eye and right-eye feedback video signals VBL and VBR are stored in the frame memories 36L and 36R.

As a result, the image data for one frame including two video data is stored in the frame memories 36L and 36R, and the read-out address signal is generated by being executed the image conversion process at the read-out address generation circuits 39L and 39R under the control of the CPU 32. Thus the left-eye and right-eye stereoscopic image output signals VL_{out} and VR_{out} consisting of the image for one frame representing the first left-eye and right-eye video signals 70L and 70R and the second left-eye and right-eye images 72L and 72R are output to the projectors 23L and 23R.

The left-eye and right-eye stereoscopic image output signals VL_{out} and VR_{out} representing the image for one frame to which the image conversion process is executed are stored in the left-eye and right-eye storing devices 63L and 63R, and then only the video signals of the second left-eye and right-eye images 72L and 72R are stored as the left-eye and right-eye switches 24L and 24R in the frame memories 36L and 36R through the left-eye and right-eye switches 24L and 24R.

Here, if the input video signal V_A is exactly the same as it has been, only the second left-eye and right-eye images 72L and 72R out of the image data for one frame stored in the frame

memories 36L and 36R are changed with the image conversion process at the read-out address generation circuits 39L and 39R.

In this state, if the read-out address generation circuits 39L and 39R are controlled by the CPU 32 so as to execute again the image conversion process, only the second left-eye and right-eye images 72L and 72R are executed the image conversion process shown in Figs. 4(A1) to 4(B2), and then output to the projectors 23L and 23R as the left-eye and right-eye stereoscopic image output signals VL_{out} and VR_{out}.

The image conversion process is executed time and again on the second left-eye and right-eye images 72L and 72R projected on the right part of the screen 24 by the projectors 23L and 23R, so that the stereoscopic image 73 formed by the feedback video signals VBL and VBR is changing sequentially in every frame. On the contrary, the stereoscopic image 71 formed by the first left-eye and right-eye images 70L and 70R which are based on the input video signal V_A with no change in its contents does not change. Therefore the operator recognizes it as the fixed image.

As described above, according to the structure shown in Fig. 7, only the desired part of the stereoscopic image generated on the screen 24 can be fed back as the left-eye and right-eye feedback video signals VBL and VBR to the frame memories 36L and 36R. It is thus possible to easily generate the stereoscopic image as if a part of the stereoscopic image is changing by the image conversion process repeatedly executed.

(4) The Other Embodiments

In the embodiments described above, previous fixation of the parameter P_z in the equation (3) for the see-through matrix P_0 to 1/16 keeps the perspective value based on the perspective. However, the present invention is not only limited to this, but if the parameter P_z is changeable according to the operation with the control panel 51 by the operator, the same effect as the above-mentioned embodiment can be obtained.

Further, in the above-mentioned embodiment of Fig. 7, feedback of a part of image projected on the screen 24 to the frame memories 36L and 36R enables to repeatedly execute the image conversion process on the part of image. However, the present invention is not only limited to this, but the image conversion process can be repeatedly executed on entire image generated on the screen 24.

Further, in the embodiment described above, projection of the left-eye and right-eye stereoscopic image output signals VL_{out} and VR_{out} on the screen 24 by the left-eye and right-eye projectors 23L and 23R generates the stereoscopic image. However, display means of stereoscopic image is not only limited to this, but the other type of image displaying apparatus, for example a head-mounted type image apparatus, can be utilized.

Further, in the above-mentioned embodiment of Fig. 7, video tape recorders are utilized in the left-eye and right-eye video signal recording devices. However, the video signal recording apparatus is not only limited to this, but the other image recording devices can be utilized such as a video disc device or a semiconductor memory devices.

Industrial Applicability

The present invention can be applied to a stereoscopic image generation apparatus which generates stereoscopic image by using video signal representing two-dimensional image.

CLAIMS

1. A stereoscopic image generation apparatus for generating video signal in order to obtain stereoscopic effects visually, comprising:

a left-eye processor for generating left-eye stereoscopic video signal from source video signal based on a spatial image conversion matrix for image conversion which converts an image represented by said source video signal to virtual spatial position, and a left-eye perspective conversion matrix for having a converted image represented by the converted conversion video signal seen through on a screen; and

a right-eye processor for generating right-eye stereoscopic video signal from said source video signal based on said spatial image conversion matrix and a right-eye perspective conversion matrix for having a converted image represented by said conversion video signal seen through on the screen.

2. The stereoscopic image generation apparatus according to claim 1, wherein

said left-eye stereoscopic video signal is a two-dimensional video signal which is seen through on said screen when an image of said conversion video signal at the virtual spatial position is looked from the spatial position of said left eye as the point of view; and said right-eye stereoscopic video signal is a two-dimensional video signal which is seen through on said screen when a image of said conversion video signal at the virtual spatial position is looked from the spatial position of said right eye as the point of view.

3. The stereoscopic image generation apparatus according to claim 1, comprising:

screen address generation means for generating sequential screen address corresponding to raster scanning; wherein

said left-eye processor and said right-eye processor operate simultaneously in response to said screen address so that said left-eye stereoscopic video signal from said left-eye processor and said right-eye stereoscopic video signal from said right-eye processor are output at the same timing with each other.

4. The stereoscopic image generation apparatus according to claim 1, wherein:

each parameter in said spatial image conversion matrix is the value set in each frame based on the image conversion operation which the operator desires; and

each parameter in said left-eye perspective conversion matrix and said right-eye perspective conversion matrix is the value previously set by the operator.

5. The stereoscopic image generation apparatus according to claim 1, wherein:

said spatial image conversion matrix T_0 is defined as follows;

$$T_0 = \begin{bmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & 0 \\ l_x & l_y & l_z & S_0 \end{bmatrix}$$

said left-eye perspective conversion matrix P_L is defined as follows;

$$P_L = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ -P_z\Delta x & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

said right-eye perspective conversion matrix P_R is defined as follows;

$$P_R = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ P_z\Delta x & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

provided that, r_{11} to r_{33} are the parameters representing spatial rotary conversion;

l_x is the parameter representing parallel movement in the direction of x-axis;

l_y is the parameter representing parallel movement in the direction of y-axis;

l_z is the parameter representing parallel movement in the direction of z-axis;

S_0 is the parameter representing two-dimensional extension and reduction;

P_z is the perspective value previously set; and

Δx is the value representing a half of distance between the right-eye and left-eye.

6. The stereoscopic image generation apparatus according to claim 5, wherein:

said left-eye perspective conversion matrix P_L is obtained as follows;

$$P_L = LP_0 \ L^{-1}$$

said right-eye perspective conversion matrix P_R is obtained as follows;

$$P_R = L^{-1} \ LP_0$$

provided that, the matrix L is defined as follows;

$$L = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \Delta x & 0 & 0 & 1 \end{bmatrix}$$

the matrix L^{-1} is defined as follows;

$$L^{-1} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\Delta x & 0 & 0 & 1 \end{bmatrix}$$

and the matrix P_0 is defined as follows;

$$P_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

7. The stereoscopic image generation apparatus according to claim 6, wherein:

said left-eye processor comprises

first storing means for storing said source video signal

temporarily; and

first read-out address generation means for generating read-out address, which is calculated based on said spatial image conversion matrix and said left-eye perspective conversion matrix, for reading out the video signal stored in said first storing means;

said right-eye processor comprises

second storing means for storing said source video signal temporarily; and

second read-out address generation means for generating read-out address, which is calculated based on said spatial conversion matrix and said right-eye perspective conversion matrix, for reading out the video signal stored in said second storing means.

8. The stereoscopic image generation apparatus according to claim 7, wherein:

read-out address (X_{mL}, Y_{mL}) supplied to said first storing means are as follows;

$$X_{mL} = \frac{1}{H_L}[\{-l_x \cdot r_{23} \cdot P_z + r_{22}(l_z P_z + S_0)\} \cdot X_S$$

$$+ \{l_y \cdot r_{13} \cdot P_z + r_{12}(l_z P_z + S_0)\} \ Y_S$$

$$+ (-r_{22} \cdot r_{13} \cdot P_z + r_{12} \cdot r_{23} \cdot P_z)]$$

$$Y_{mL} = \frac{1}{H_L}[\{(l_x - l_z P_z \Delta x) r_{23} P_z$$

$$- (r_{21} - r_{23} P_z \Delta x) \cdot (l_z P_z + S_0)\} \ X_S$$

$$+ \{-(l_x - l_z P_z \Delta x \ \cdot r_{13} \cdot P_z$$

$$+ (r_{11} - r_{13} P_z \Delta x) \cdot (l_z P_z + S_0)\} \ Y_S$$

$$+ \{r_{21} - r_{23} P_z \Delta x) \cdot r_{13} \cdot P_z$$

$$- (r_{11}-r_{13}P_z \Delta x) \cdot r_{23} \cdot P_z\}]$$

provided that, the definition will be made by the following equation;

$$H_L = \{-r_{22}(l_x - l_zP_z \Delta x) + (r_{21} - r_{23}P_z \Delta x) \cdot l_y\} X_S$$
$$+ \{r_{12}(l_x - l_zP_z \Delta x) - (r_{11} - r_{13}P_z \Delta x) \cdot l_y\} Y_S$$
$$+ \{-r_{12} \cdot (r_{21} - r_{23}P_z \Delta x) + (r_{11} - r_{13}P_z \Delta x) r_{22}\}$$

read-out address (X_{mR}, Y_{mR}) supplied to said second storing means are;

$$X_{mR} = \frac{1}{H_R}[\{-l_x \cdot r_{23} \cdot P_z + r_{22}(l_zP_z + S_0)\} \cdot X_S$$
$$+ \{l_y \cdot r_{13} \cdot P_z + r_{12}(l_zP_z + S_0)\} Y_S$$
$$+ (-r_{22} \cdot r_{13} \cdot P_z + r_{12} \cdot r_{23} \cdot P_z)]$$

$$Y_{mR} = \frac{1}{H_R}[\{(l_x + l_zP_z\Delta x) r_{23}P_z$$
$$- (r_{21} + r_{23}P_z \Delta x) \cdot (l_zP_z + S_0)\} X_S$$
$$+ \{-(l_x + l_zP_z \Delta x \cdot r_{13} \cdot P_z$$
$$+ (r_{11} + r_{13}P_z \Delta x) \cdot (l_zP_z + S_0)\} Y_S$$
$$+ \{r_{21} + r_{23}P_z \Delta x) \cdot r_{13}P_z$$
$$- (r_{11} + r_{13}P_z \Delta x) \cdot r_{23} \cdot P_z\}]$$

provided that, the definition will be made as follows;

$$H_R = \{-r_{22}(l_x+l_zP_z \Delta x) + (r_{21} + r_{23}P_z \Delta x) \cdot l_y\} X_S$$

$$+ \{r_{12}(l_x+l_zP_z\Delta x) - (r_{11} + r_{13}P_z\Delta x)\cdot l_y\} Y_s$$

$$+ \{-r_{12}\cdot(r_{21}+r_{23}P_z\Delta x) + (r_{11} + r_{13}P_z\Delta x)r_{22}\}$$

and, X_s and Y_s are screen addresses corresponding to the raster scanning.

9. The stereoscopic image generation apparatus according to claim 8, wherein

said same screen addresses are sequentially supplied to both of said first read-out address generation means and said second read-out address generation means.

10. The stereoscopic image generation apparatus according to claim 7, comprising:

write-in address generation means for generating write-in address for writing said source video signal in said first storing means and said second storing means, and wherein:

the same write-in addresses are supplied from said write-in address generation means to said first storing means and said second storing means, respectively.

11. The stereoscopic image generation apparatus according to claim 1, wherein:

key signal corresponding to said source video signal and background video signal used for the background of said source video signal are supplied to said left-eye processor and said right-eye processor, respectively;

said left-eye processor comprises

first image conversion means for executing the first spatial image conversion to said source video signal and for executing the

same spatial image conversion as said first spatial image conversion to said key signal based on said spatial image conversion matrix and said left-eye perspective conversion matrix; and

first video signal composition means for composing the video signal converted by said first image conversion means with said background video signal based on the key signal converted by said first image conversion means; and

said right-eye processor comprises

second image conversion means for executing the second spatial image conversion to said source video signal and for executing the same spatial image conversion as said second spatial image conversion to said key signal based on said spatial image conversion matrix and said right-eye perspective conversion matrix; and

second video signal composition means for composing the video signal converted by said second image conversion means with said background video signal based on the key signal converted by said second image conversion means.

12. The stereoscopic image generation apparatus according to claim 1, further comprising:

a first recording/reproducing device for recording the output video signal output from said left-eye processor to a recording medium and for reproducing the recorded video signal from the recording medium;

a second recording/reproducing device for recording the output video signal output from said right-eye processor to a

recording medium and for reproducing the recorded video signal from the recording medium;

first key signal generation means for generating key signal from the first reproduced video signal reproduced from said first recording/reproducing device;

second key signal generation means for generating key signal from the second reproduced video signal reproduced from said second recording/reproducing device, and wherein:

said left-eye processor

receives the first reproduced video signal reproduced from said first recording/reproducing device, the key signal generated by said first key signal generation means, and background video signal used for the background of said source video signal;

executes first spatial image conversion to said first reproduced video signal and the same spatial image conversion as said first spatial image conversion to said key signal based on said spatial image conversion matrix and said left-eye perspective conversion matrix; and

composites the video signal converted by said first image conversion means with said background video signal based on the key signal converted by said first image conversion means; and

said right-eye processor

receives the second reproduced video signal reproduced from said second recording/reproducing device, the key signal generated by said second key signal generation means, and said background video signal;

executes the second spatial image conversion to said second

reproduced video signal and the same spatial image conversion as said second spatial image conversion to said key signal based on said spatial image conversion matrix and said right-eye perspective conversion matrix; and

composites the video signal converted by said second image conversion means with said background video signal based on the key signal converted by said second image conversion means.

13. The stereoscopic image generation apparatus according to claim 12, wherein

the key signal generated by said first key signal generation means is the same signal as the key signal generated by said second key signal generation means.

14. A video signal generation apparatus for generating video signal for visual stereoscopic effects, comprising:

image conversion means for converting an image represented by source video signal to a virtual spatial position;

left-eye video signal generation means for generating left-eye video signal representing an image seen through on a screen surface based on the virtual spatial position where there is the image of the converted video signal converted by said image conversion means and left-eye spatial position; and

right-eye video signal generation means for generating right-eye video signal representing an image seen through on a screen surface based on the virtual spatial position where there is the image of said converted video signal and right-eye spatial position.

15. The video signal generation apparatus according to claim 14,

wherein:

said image conversion means converts said source video signal based on spatial image conversion matrix;

said left-eye video signal generation means generates said left-eye video signal based on left-eye perspective conversion matrix; and

said right-eye video signal generation means generates said right-eye video signal based on right-eye perspective conversion matrix.

16. The video signal generation apparatus according to claim 14, further comprising:

screen address generation means for generating sequential screen address corresponding to raster scanning, and wherein:

said left-eye video signal generation means and said right-eye video signal generation means operate at the same time in response to said screen address.

17. The video signal generation apparatus according to claim 15, wherein:

said spatial image conversion matrix T_0 is defined as follows;

$$T_0 = \begin{bmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & 0 \\ l_x & l_y & l_z & S_0 \end{bmatrix}$$

said left-eye perspective conversion matrix P_L is defined as follows;

$$P_L = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ -P_z\Delta x & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

said right-eye perspective conversion matrix P_R is defined as follows;

$$P_R = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ P_z\Delta x & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

provided that, r_{11} to r_{33} are parameters representing spatial rotary conversion;

l_x is a parameter representing parallel movement in the direction of x-axis;

l_y is a parameter representing parallel movement in the direction of y-axis;

l_z is a parameter representing parallel movement in the direction of z-axis;

S_0 is a parameter representing two-dimensional extension and reduction; and

Δx is a value showing a half of distance of a right eye and a left eye.

18. The video signal generation apparatus according to claim 17, wherein:

said left-eye perspective conversion matrix P_L is obtained as follows;

$$P_L = LP_0 L^{-1}$$

said right-eye perspective conversion matrix P_R is obtained as follows;

$$P_R = L^{-1}LP_0$$

provided that, the matrix L is defined as follows;

$$L = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \Delta x & 0 & 0 & 1 \end{bmatrix}$$

the matrix L^{-1} is defined as follows;

$$L^{-1} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\Delta x & 0 & 0 & 1 \end{bmatrix}$$

and the matrix P_0 is defined as follows:

$$P_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

19. The video signal generation apparatus according to claim 18, wherein:

said left-eye video signal generation means comprises

first storing means for storing said source video signal temporarily; and

first read-out address generation means for generating read-out address for reading out the video signal which is calculated based on said spatial image conversion matrix and said left-eye perspective conversion matrix and is stored in said first storing means;

said right-eye video signal generation means comprises

second storing means for storing said source video signal temporarily; and

second read-out address generation means for generating read-out address for reading out the video signal which is calculated based on said spatial image conversion matrix and said right-eye perspective conversion matrix and is stored in said second storing means.

20. The video signal generation apparatus according to claim 19, wherein:

the read-out address (X_{mL}, Y_{mL}) supplied to said first storing means is as follows;

$$X_{mL} = \frac{1}{H_L}[\{-l_x \cdot r_{23} \cdot P_z + r_{22}(l_z P_z + S_0)\} \cdot X_s$$

$$+ \{l_y \cdot r_{13} \cdot P_z + r_{12}(l_z P_z + S_0)\} Y_s$$

$$+ (-r_{22} \cdot r_{13} \cdot P_z + r_{12} \cdot r_{23} \cdot P_z)]$$

$$Y_{mL} = \frac{1}{H_L}[\{(l_x - l_z P_z \Delta x) r_{23} P_z$$

$$- (r_{21} - r_{23} P_z \Delta x) \cdot (l_z P_z + S_0)\} X_s$$

$$+ \{-(l_x - l_z P_z \Delta x \cdot r_{13} \cdot P_z$$

$$+ (r_{11} - r_{13} P_z \Delta x) \cdot (l_z P_z + S_0)\} Y_s$$

$$+ \{r_{21}-r_{23}P_z \Delta x) \cdot r_{13}P_z$$
$$- (r_{11}-r_{13}P_z \Delta x) \cdot r_{23} \cdot P_z\}]$$

provided that, definition is done as follows;

$$H_L = \{-r_{22}(l_x-l_zP_z \Delta x) + (r_{21} - r_{23}P_z \Delta x) \cdot l_y) X_s$$
$$+ \{r_{12}(l_x-l_zP_z \Delta x) - (r_{11} - r_{13}P_z \Delta x) \cdot l_y\} Y_s$$
$$+ \{-r_{12} \cdot (r_{21} - r_{23}P_z \Delta x) + (r_{1i} - r_{13}P_z \Delta x) r_{22}\}$$

the read-out address (X_{mR}, Y_{mR}) supplied to said second storing means is as follows;

$$X_{mR} = \frac{1}{H_R} [\{-l_x \cdot r_{23} \cdot P_z + r_{22}(l_zP_z + S_0)\} \cdot X_s$$
$$+ \{l_y \cdot r_{13} \cdot P_z + r_{12}(l_zP_z + S_0)\} Y_s$$
$$+ (-r_{22} \cdot r_{13} \cdot P_z + r_{12} \cdot r_{23} \cdot P_z)]$$

$$Y_{mR} = \frac{1}{H_R} [\{(l_x + l_zP_z\Delta x) r_{23}P_z$$
$$- (r_{21} + r_{23}P_z \Delta x) \cdot (l_zP_z + S_0)\} X_s$$
$$+ \{-(l_x + l_zP_z \Delta x \cdot r_{13} \cdot P_z$$
$$+ (r_{11} + r_{13}P_z \Delta x) \cdot (l_zP_z + S_0)\} Y_s$$
$$+ \{r_{21} + r_{23}P_z \Delta x) \cdot r_{13}P_z$$
$$- (r_{11} + r_{13}P_z \Delta x) \cdot r_{23} \cdot P_z\}]$$

provided that, definition is done as follows:

$$H_R = \{-r_{22}(l_x+l_zP_z \Delta x) + (r_{21} + r_{23}P_z \Delta x) \cdot l_y\} X_s$$

$$+ \{r_{12}(l_x+l_zP_z\Delta x) - (r_{11} + r_{13}P_z\Delta x)\cdot l_y\}\ Y_s$$

$$+ \{-r_{12}\cdot(r_{21}+r_{23}P_z\Delta x) + (r_{11} + r_{13}P_z\Delta x)r_{22}\}$$

and provided that, X_s and Y_s are screen addresses.

21. The video signal generation apparatus according to claim 20, wherein

the same screen addresses are sequentially supplied to both said first read-out address generation means and said second read-out address generation means corresponding to raster scanning.

22. The video signal generation apparatus according to claim 19, comprising:

write-in address generation means for generating write-in address for writing said source video signal in said first storing means and said second storing means, and wherein:

same write-in address is supplied from said write-in address generation means to the write-in address supplied to said first storing means and said second storing means.

23. The video signal generation apparatus according to claim 15, wherein:

key signal corresponding to said source video signal and background video signal used for the background of said source video signal are supplied to said left-eye video signal generation means and said right-eye video signal generation means;

said left-eye video signal generation means comprises

first image conversion means for executing first spatial image conversion to said source video signal and for executing the same spatial image conversion as the first spatial image

conversion to said key signal based on said spatial image conversion matrix and said left-eye perspective conversion matrix; and

first video signal composition means for composing the video signal converted by said first image conversion means with said background video signal based on the key signal converted by said first image conversion means;

said right-eye video signal generation means comprises

second image conversion means for executing second spatial image conversion to said source video signal and for executing the same spatial image conversion as the second spatial image conversion to said key signal based on said spatial image conversion matrix and said right-eye perspective conversion matrix; and

second video signal composition means for composing the video signal converted by said second image conversion means with said background video signal based on the key signal converted by said second image conversion means.

24. The video signal generation apparatus according to claim 15, comprising:

first recording/reproducing device for recording output video signal output from said left-eye video signal generation means to a recording medium and for reproducing the recorded video signal from the recording medium;

second recording/reproducing device for recording output video signal output from said right-eye video signal generation means to a recording medium and for reproducing the recorded video

signal from the recording medium;

first key signal generation means for generating key signal from the first reproduced video signal reproduced from said first recording/reproducing device; and

second key signal generation means for generating key signal from the second reproduced video signal reproduced from said second recording/reproducing device, wherein:

said left-eye video signal generation means

receives the first reproduced video signal reproduced from said first recording/reproducing device, the key signal generated by said first key signal generation means, and background video signal used for the background of said source video signal;

executes first spatial image conversion to said first reproduced video signal and the same spatial image conversion as said first spatial image conversion to said key signal based on said spatial image conversion matrix and said left-eye perspective conversion matrix; and

composites the video signal converted by said first image conversion means with said background video signal based on the key signal converted by said first image conversion means; wherein

said right-eye processor

receives the second reproduced video signal reproduced from said second recording/reproducing device, the key signal generated by said second key signal generation means and said background video signal;

executes second spatial image conversion to said second reproduced video signal and the same spatial image conversion as

said second spatial image conversion to said key signal based on said spatial image conversion matrix and said right-eye perspective conversion matrix; and

composites the video signal converted by said second image conversion means with said background video signal based on the key signal converted by said second image conversion means.

25. The video signal generation apparatus according to claim 24, wherein

the key signal generated by said first key signal generation means is the same key signal as the key signal generated by said second key signal generation means.

26. A video signal generation method for generating video signal for obtaining the virtual stereoscopic effects, comprising:

(a) first step of converting source video signal to virtual spatial position;

(b) second step of generating left-eye video signal seen through on a screen surface based on the virtual spatial position of the converted video signal converted at said first step and spatial position of the left eye; and

(c) third step of generating right-eye video signal seen through on a screen surface based on the virtual spatial position of the converted video signal converted at said first step and spatial position of the right eye.

27. The video signal generation method according to claim 26, wherein:

said source video signal is converted at said first step based on spatial image conversion matrix having parameters

corresponding to spatial image conversion operation which the operator desires;

said left-eye video signal is generated at said second step based on left-eye perspective conversion matrix having parameters previously set by the operator; and

said right-eye video signal is generated at said third step based on right-eye perspective conversion matrix having parameters previously set by the operator.

28. The video signal generation method according to claim 26, further comprising:

fourth step of generating sequential screen address corresponding to raster scanning; and wherein

process at said first, second and third steps are executed according to said screen address.

29. The video signal generation method according to claim 27, wherein:

said spatial image conversion matrix T_0 is defined as follows;

$$T_0 = \begin{bmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & 0 \\ l_x & l_y & l_z & S_0 \end{bmatrix}$$

said left-eye perspective conversion matrix P_L is defined as follows;

$$P_L = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ -P_z\Delta x & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

said right-eye perspective conversion matrix P_R is defined as follows;

$$P_R = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ P_z\Delta x & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

provided that, r_{11} to r_{33} are the parameters representing spatial rotary conversion;

l_x is the parameter representing parallel movement in the direction of x-axis;

l_y is the parameter representing parallel movement in the direction of y-axis;

l_z is the parameter representing parallel movement in the direction of z-axis;

S_0 is the parameter representing two-dimensional extension and reduction;

P_z is the perspective value previously set; and

Δx is the value representing a half of distance between the right-eye and left-eye.

30. The video signal generation apparatus according to claim 29, wherein:

said left-eye perspective conversion matrix P_L is obtained as follows;

$$P_L = LP_0\ L^{-1}$$

said right-eye perspective conversion matrix P_R is obtained as

follows;

$$P_R = L^{-1} L P_0$$

provided that, the matrix L is defined as follows;

$$L = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \Delta x & 0 & 0 & 1 \end{bmatrix}$$

the matrix L^{-1} is defined as follows;

$$L^{-1} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\Delta x & 0 & 0 & 1 \end{bmatrix}$$

and the matrix P_0 is defined as follows;

$$P_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

31. The video signal generation method according to claim 30, comprising:

fifth step of temporarily storing said source video signal to first storing means and second storing means;

sixth step of generating left-eye read-out address for reading out the video signal stored in said first storing means based on said spatial image conversion matrix and said left-eye perspective conversion matrix; and

seventh step of generating right-eye read-out address for reading out the video signal stored in said second storing means based on said spatial image conversion matrix and said right-eye perspective conversion matrix.

32. The video signal generation method according to claim 31, wherein:

said left-eye read-out address (X_{mL}, Y_{mL}) are;

$$X_{mL} = \frac{1}{H_L}[\{-l_x \cdot r_{23} \cdot P_z + r_{22}(l_z P_z + S_0)\} \cdot X_s$$
$$+ \{l_y \cdot r_{13} \cdot P_z + r_{12}(l_z P_z + S_0)\} Y_s$$
$$+ (-r_{22} \cdot r_{13} \cdot P_z + r_{12} \cdot r_{23} \cdot P_z)]$$

$$Y_{mL} = \frac{1}{H_L}[\{(l_x - l_z P_z \Delta x) r_{23} P_z$$
$$- (r_{21} - r_{23} P_z \Delta x) \cdot (l_z P_z + S_0)\} X_s$$
$$+ \{-(l_x - l_z P_z \Delta x \cdot r_{13} \cdot P_z$$
$$+ (r_{11} - r_{13} P_z \Delta x) \cdot (l_z P_z + S_0)\} Y_s$$
$$+ \{r_{21} - r_{23} P_z \Delta x) \cdot r_{13} P_z$$
$$- (r_{11} - r_{13} P_z \Delta x) \cdot r_{23} \cdot P_z\}]$$

provided that;

$$H_L = \{-r_{22}(l_x - l_z P_z \Delta x) + (r_{12} - r_{23} P_z \Delta x) \cdot l_y\} X_s$$
$$+ \{r_{12}(l_x - l_z P_z \Delta x) - (r_{11} - r_{13} P_z \Delta x) \cdot l_y\} Y_s$$
$$+ \{-r_{12} \cdot (r_{21} - r_{23} P_z \Delta x) + (r_{11} - r_{13} P_z \Delta x) r_{22}\}$$

said right-eye read-out address (X_{mR}, Y_{mR}) are as follows;

$$X_{mR} = \frac{1}{H_R}[\{-l_x \cdot r_{23} \cdot P_z + r_{22}(l_zP_z + S_0)\} \cdot X_s$$

$$+ \{l_y \cdot r_{13} \cdot P_z + r_{12}(l_zP_z + S_0)\} Y_s$$

$$+ (-r_{22} \cdot r_{13} \cdot P_z + r_{12} \cdot r_{23} \cdot P_z)]$$

$$Y_{mR} = \frac{1}{H_R}[\{(l_x + l_zP_z\Delta x) r_{23}P_z$$

$$- (r_{21} + r_{23}P_z \Delta x) \cdot (l_zP_z + S_0)\} X_s$$

$$+ \{-(l_x + l_zP_z \Delta x \cdot r_{13} \cdot P_z$$

$$+ (r_{11} + r_{13}P_z \Delta x) \cdot (l_zP_z + S_0)\} Y_s$$

$$+ \{r_{21} + r_{23}P_z \Delta x) \cdot r_{13}P_z$$

$$- (r_{11} + r_{13}P_z \Delta x) \cdot r_{23} \cdot P_z\}]$$

provided that, it is defined as follows;

$$H_R = \{-r_{22}(l_x+l_zP_z \Delta x) + (r_{21} + r_{23}P_z \Delta x) \cdot l_y\} X_s$$

$$+ \{r_{12}(l_x+l_zP_z \Delta x) - (r_{11} + r_{13}P_z \Delta x) \cdot l_y\} Y_s$$

$$+ \{-r_{12} \cdot (r_{21}+r_{23}P_z \Delta x) + (r_{11} + r_{13}P_z \Delta x) r_{22}\}$$

and, X_s and Y_s are screen addresses corresponding to the raster scanning.

33. A video signal generation method for generating video signal for obtaining virtual stereoscopic effects, comprising:

(a) first step of receiving source video signal, source key signal corresponding to said source video signal, and background video signal used for the background of said source video signal;

(b) second step of converting said source video signal and said source key signal to virtual spatial position;

(c) third step of generating left-eye video signal and left-eye key signal seen through on a screen surface based on virtual spatial positions of the converted video signal and the converted key signal both converted at said second step and the spatial position of the left eye;

(d) fourth step of composing said left-eye video signal and said background video signal based on said left-eye key signal;

(e) fifth step of generating right-eye video signal and right-eye key signal seen through on a screen surface based on virtual spatial positions of the converted video signal and the converted key signal both converted at said second step and the spatial position of the right eye; and

(f) sixth step of composing said right-eye video signal and said background video signal based on said right-eye key signal.

34. A video signal generation system for generating video signal for obtaining virtual stereoscopic effects, comprising:

(a) first step of converting source video signal to virtual spatial position:

(b) second step of generating left-eye video signal seen through on a screen surface based on the virtual spatial position of the converted video signal converted at said first step and the spatial position of the left eye;

(c) third step of generating right-eye video signal seen through on a screen surface based on the virtual spatial position of the converted video signal converted at said first step and the spatial position of the right eye; and

(d) fourth step of displaying said left-eye video signal and said

right-eye video signal on the screen surface at the same time.

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 H04N13/02, G06T15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^6 H04N13/02, G06T15/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1971 - 1997
Kokai Jitsuyo Shinan Koho 1971 - 1997

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 7-226958, A (Sanyo Electric Co., Ltd.), August 22, 1995 (22. 08. 95) (Family: none)	1 - 34
A	JP, 7-200870, A (Sharp Corp.), August 4, 1995 (04. 08. 95) (Family: none)	1 - 34
A	JP, 7-182533, A (Sanyo Electric Co., Ltd.), July 21, 1995 (21. 07. 95) (Family: none)	1 - 34

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search	Date of mailing of the international search report
January 14, 1997 (14. 01. 97)	January 28, 1997 (28. 01. 97)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.